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Better data for smarter decision-making

The proposed Car Club-Local Authority Data Standard

Chenyang Wu, Aruna Sivakumar, Scott Le Vine
Urban Systems Lab, Imperial College London
December 2020

Imperial College London

LONDON COUNCILS

The Royal Automobile Club Foundation for Motoring Ltd is a transport policy and research organisation which explores the economic, mobility, safety and environmental issues relating to roads and their users. The Foundation publishes independent and authoritative research with which it promotes informed debate and advocates policy in the interest of the responsible motorist.

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About the Author

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Disclaimer

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Foreword

Car clubs (or car sharing outside of the UK) offer a car on a short-term basis without the expense and upkeep of maintaining one's own personal vehicle. Although this might feel like a relatively new scheme, having only really begun to scale-up in the UK in 2008, the concept has been around since the 1940's.

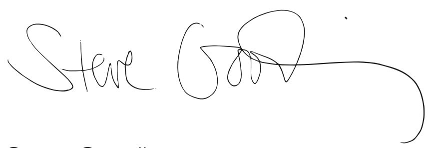
Car clubs offer many benefits both to their members and potentially to policy makers. For members they can offer convenient access to vehicles as and when they need them without all the expense and hassle of ownership (bearing in mind that most privately owned cars spend the vast majority of their lives sat still somewhere). Car clubs may offer newer, cleaner vehicles, including electric options, and if members choose no longer to own their own vehicles they can lead to more efficient use of the kerbside, particularly in places where houses don't have off-road parking, and might result in members considering whether a they need to use a car as much, rather than making more local trips on foot, by bike or on public transport.

While car clubs generate a mass of detailed trip data as part of their business activities that data is not routinely used in the UK to help inform evidence-based policies. However, since car clubs rely on local authorities to accommodate their needs for on-street parking in return for to achieving public policy goals we saw fertile ground for promoting a fresh approach: a data sharing framework between car club operators and local authorities, based on those already in existence around the world. A framework that would give local authorities useful information whilst minimising the burden on car clubs, by bringing all sides together to thrash out a standard reporting template.

And so, after much hard work by researchers at Imperial College this report presents the Car Club-Local Authority Data Standard (CLADS) – a framework based on four data files along with one summary statistics file, to include user information, parking location, vehicle distribution and trip information, to be shared every quarter. This report also showcases how CLADS could be used by local authorities by giving three different illustrative scenarios.

We recognise this is just the first step – there is still work to be done by car clubs and local authorities to set the reporting framework into a wider relationship that ensures data is maintained, data quality preserved, commercial confidentiality protected, and, perhaps, most important of all, that data is used to inform better decisions.

A first step, but a significant one, because it comes from engagement with both the car clubs and the local authorities, and on that basis, we heartily endorse its rapid adoption.



Steve Gooding
Director, RAC Foundation

Foreword

The Covid-19 pandemic has had a profound impact on Londoners, and London's economy – impacts that are likely to continue to be felt for years to come. However, through the pandemic we have seen that Londoners are highly capable of adapting their behaviours to meet and overcome adverse conditions, as seen in the dramatic rise in home-working, and the increase in the use of active travel and shopping locally – particularly at the height of the lockdown.

As we continue to navigate towards a safe, post-Covid environment, it is imperative that we do not return to business as usual, when London's roads were often congested, dangerous, and unwelcoming places for people to walk or cycle near. By helping to reduce the number of vehicles both moving and parked on the road and providing access to a clean fleet of shared vehicles, car clubs could play an important role in this journey towards a cleaner, more sustainable future.

London Councils is committed to working with key partners to support the further development of the car club sector and has worked closely with the RAC Foundation and Imperial College London on this project to explore ways of improving data-sharing between car club operators and London local government. The proposed Car Club Local Authority Data Standard (CLADS) will enable a joint understanding of car club usage in London, and inform a coordinated approach to future car club policy.

Working together, we can continue to transform our city, using local knowledge, and investing in the right infrastructure and expertise to create a future London that is not only home to more people, but is a better place for all of us to live, work and enjoy.

Mayor Philip Glanville
Chair of London Councils' Transport and Environment Committee

Foreword

Car clubs have been operating successfully in the UK for more than ten years, providing flexible, affordable and sustainable road transport to tens of thousands of people.

The sector can be rightly proud of the societal benefits it brings, reducing congestion, emissions and private car ownership and encouraging the use of public transport and active travel.

It is surprising then, that the UK car club market has not grown more rapidly or come close to reaching its full potential. The business model relies on a close and symbiotic link between operators and local transport policymakers, but the quality of these working relationships varies hugely across the country. Success stories have not always been replicated and valuable lessons have not been learnt.

These missed chances are put into even sharper focus as the economic outlook deteriorates and the UK's sustainable transport targets get more ambitious. An effective, proportionate and scaleable data sharing framework could unlock these opportunities, providing a vital roadmap for under-resourced local authorities.

This report could not have come at a better time. The framework it proposes will deliver powerful insights that can unlock further investment in the future potential of car clubs.

This progress cannot happen in isolation. It is time for national Government to take a more strategic approach to shared and integrated transport by investing for the long term and bringing operators, policymakers and local authorities together to ensure that this money is spent wisely and fairly.

Gerry Keaney
CEO of the BVRLA

Executive Summary

Car clubs (known as car sharing in North America and many other countries outside the UK) are short-term car hire services that provide mobility benefits to their users and can help support the sustainable transport targets of local authorities. Car clubs broadly operate two kinds of services: a back-to-base or round trip (RT) car club service; and/or a free-floating car sharing (FFCS) service, which is also referred to as a point-to-point service.

Car clubs in the UK typically seek dedicated access to on-street parking; thus, local authorities have a reasonable desire to understand the impacts of their operations. Failure to co-ordinate between operators and local authorities means that the benefits of car clubs will not be fully realized.

And yet, a general data sharing agreement between car club operators and local authorities has not been well established. Data exchanges are ad hoc and the lack of a common data sharing framework is problematic in several respects.

The objective of this report is to propose a data sharing framework for car club operators and local authorities in the UK, to be known as Car Club-Local Authority Data Standard (CLADS).

Developing this framework involved three work streams: identifying and critically analysing existing related data standards; interviewing senior staff at locations abroad facing similar issues; and hosting a series of three workshops with invited stakeholders.

CLADS as a proposal for static data delivery considers user privacy and operators' commercial considerations. The need to accommodate CLADS within real-time data when data anonymisation techniques are more advanced is discussed.

The CLADS framework consists of one summary statistics file and four data files, that is, user information, parking location, vehicle distribution and trip information. All data files are to be shared by the car club operators on a quarterly basis. The contents of these data files are as follows:

- Summary statistics: this file presents an overview of the car club operations in a quarter. The file contains the number of active members, the number of members joining/leaving in that quarter, total number of members (active and inactive), number of on-street vehicles, average booking duration and distance, average use of on-street parking, percentage availability of vehicles, and number of off-street vehicles. All information is averaged for each car club vehicle location (or parking bay if the parking bays hold only one vehicle) over the quarter.
- User information: the user information data is aggregated to the Lower Layer Super Output Area (LSOA, see Ministry of Housing, Communities and Local Government (2020) for definition) level and contain the details for all members (active and inactive) of the car club service. The contents include the operator's name, LSOA where the user is located, anonymised user ID, user type (private or corporate)

and age of the user. Contents such as other socioeconomic characteristics are optional. The anonymised user ID must be consistent across reporting periods.

- Parking location: this file is required for RT car club services only. The information is aggregated to the street level. The contents include operator's name, local authority, street address and number of vehicles by type of parking bay (local authority concession or third-party parking).
- Vehicle distribution: this file is required for FFCS services only. The information is updated four times a day but shared with the local authorities on a quarterly basis. The information is aggregated to the local authority level. The contents include operator's name, number of available FFCS vehicles within the local authority at the time of updating, and update time and date.
- Trip information: the level of spatial granularity for this file is different for RT and FFCS services. For RT, the information is aggregated to the street level, whereas for FFCS the exact latitude/longitude of the trip start/end location are to be shared. The contents include operator's name, trip ID, anonymised user ID from the user information file, vehicle plate number, trip start/end time, trip start/end location (street address for RT and latitude/longitude for FFCS), total mileage during the trip. Where available and relevant, also the state of charge at the pick-up/drop-off time (for electric vehicles (EVs) only) and charging episodes during trips (EVs only).

Prospective use cases of CLADS are established through three fictional case studies (for three local authority transport officers working at two London boroughs).

Thus, this report sets out the technical details proposed for a data sharing standard that is beneficial and acceptable to both car club operators and local authorities in the UK. Further work is needed to encourage adoption. In particular, several important questions are to be tackled before CLADS can be adopted. These include:

- Who will own the data standard? Who will assess and maintain it going forward?
- Who will retain physical custody of the archived data?
- How will the data be shared? In what format and via which medium?
- Will the data be entirely or partially sharable across local authorities, or only bilaterally between each operator and each local authority?
- Can the data be shared with other planning agencies or other public bodies?
- Is open access to be provided to the external research community?
- What clauses need to be added to the contract to protect data privacy and commercially sensitive information?

The answers to these questions are essential in crafting an appropriate contract between the car club operator and the local authority.

The report ends with a discussion of these issues. We also explore possible extensions of this data sharing framework, such as real-time data sharing and incorporating other shared mobility services.

We hope that this study will resolve some of the existing issues in the UK car club sector and go on to benefit the transport system management and further development of the UK's car club sector.

1. Introduction

1.1 Background on car clubs

Car clubs (car sharing in North America and many other countries outside the UK) offer a way to use a car when needed, without the expense and upkeep of maintaining one's own personal vehicle. They offer various potential efficiencies:

- Both national and global evidence document the potential to reduce urban land allocated to parking private cars (Balac et al., 2017; Tchervenkov et al., 2018).
- By eliminating the relatively high fixed costs of motoring (car purchase, insurance, etc.), there is the potential to provide car access to persons excluded from car ownership for economic reasons (Shaheen & Sperling, 1998).
- By increasing the perceived per-journey cost of car access, relative to personal cars, car club users are incentivised to consider whether the car is the most appropriate form of travel for each of their journeys. The net effect is increased use of active travel and public transport (Becker et al., 2017; Le Vine et al., 2014; Martin & Shaheen, 2011; Namazu & Dowlatabadi, 2018).

Motivated to support achieving these potential efficiencies, the RAC Foundation has been at the forefront of this research agenda over the past decade (Cairns, 2011; Le Vine, 2012).

A very brief history of car clubs

The Sefage (Selbstfahrergenossenschaft) system in Switzerland, beginning in 1948, is frequently cited as the first 'modern' car club. Following this attempt, several other car clubs appeared in Europe. Example operators are Procotip in Montpellier, France (1971) and Witkar in Amsterdam, the Netherlands (1973). One of the earliest car clubs still operating is Switzerland's Mobility Carsharing cooperative, founded in the 1990s. Green Car (founded in 1975) was a pioneering UK car club.

Ubiquitous smartphones in the hands of members of the public allow a seamless user experience than the early generations of car clubs, which relied on voice calls to make bookings, keysafes for storing car keys and paper-and-pencil accounting systems. The UK's car club market began to scale around 2008, reaching 60,000 users compared to under 5,000 in 2005.

Car clubs are one of a number of technology-enabled 'shared mobility services' that have attained growing prominence. Beyond car clubs, other forms of travel that fall within the shared mobility umbrella include ridesourcing, bike sharing and shared micromobility, such as e-bikes and e-scooters.

Taxonomy and definition of shared mobility and supporting terms

The terminology used in the field of shared mobility is confusing. For example, car club is termed as 'car sharing' in North America and many other countries outside the UK, whereas car sharing means several people travelling in the same vehicle in the UK. To take another example, ridesourcing is sometimes referred to as ridehailing in the academic literature.

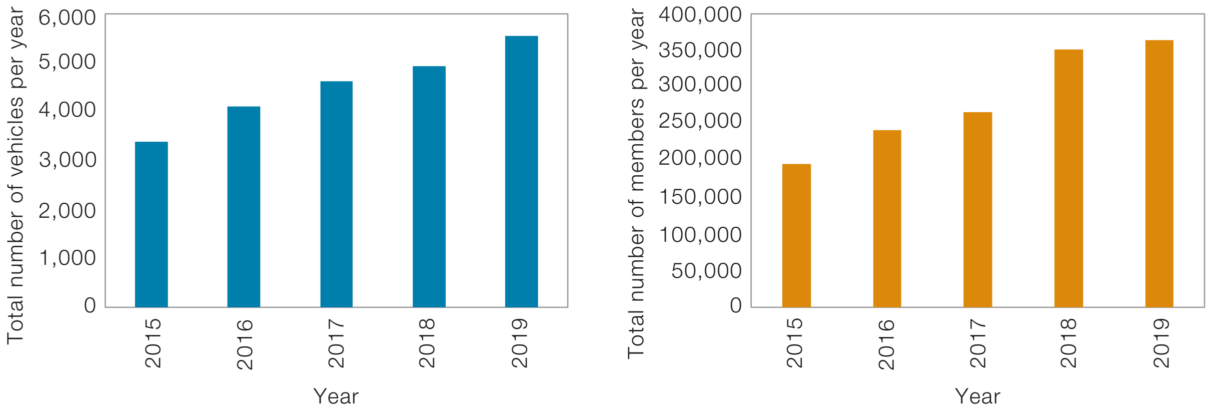
To avoid this confusion, the standards organisation SAE International recently published the taxonomy and definition of shared mobility in 2018 (SAE International, 2018). Car club, as well as other shared mobility services (bike sharing, ride sharing, etc.) are clearly defined in this standard.

The charity CoMoUK provides the UK's accreditation scheme for car clubs and has tracked the development of the marketplace through a detailed annual survey of users and operators (initiated in 2007; most recent edition in 2019) (CoMoUK, 2019). Today (mid-2020), car clubs in the UK are most widespread in London, with some 250,000[1] registered members[2] and 2,500 shared vehicles (CoMoUK, 2018). Outside London, there are 25,000 users and 800 vehicles in the rest of England and Wales (CoMoUK and Steer, 2018), and 25,000 users per 500 vehicles in Scotland. This pattern is not unusual globally, with car clubs generally finding the greatest success in dense urban neighbourhoods. An exception to this appears to be the case in Karlsruhe, Germany, which outperforms all the bigger cities with regards to car sharing.

1 Note that the statistics presented here predate the exit of two key operators in London, that is, Share Now and Bluecity.

2 The Car Club-Local Authority Data Standard will allow local authorities to identify the proportion of registered car club members who are active (in terms of recent usage) versus inactive; see the example analysis in Section 6.1.

Figure 1.1: Car club market size change in the UK from 2015 to 2019



Source: Modified from CoMoUK, 2020a.

Car clubs can have a variety of service characteristics, as shown in Table 1.1. The 'back-to-base' or 'round trip (RT)' type of service is most prevalent and best-established in the UK.

Table 1.1: Types of car club

Car club type	Does the user pick up and drop off the vehicle at the same location?	Does the user pick up and drop off vehicles at *dedicated car club stations*?	Who owns the shared vehicles?	Examples of operators (CoMoUK, 2020b)
Back-to-base (also called RT)	Yes.	Yes.	Car club operator.	Co-wheels, Enterprise, Getaround, Ubeeqo, Zipcar.
Point to point	No.	Yes.	Car club operator.	None in the UK at present (former example is Bluecity).
Free-floating car sharing (FFCS)	No.	No.	Car club operator.	Zipcar Flex (former examples include Share Now and car2go).
Peer to peer	N/A	N/A	Private car owners wishing to generate income by hiring out their vehicle.	Getaround, Hiyacar, Turo.

Source: CoMoUK, 2020b

The car club sector in the UK encompasses a range of stakeholder types:

- **Car club operators** (see Table 1.1).
- **Local Authorities**: Local authorities in Greater London and local transport authorities outside the metropolitan areas and London. They are motivated to enlist car clubs to provide useful services to residents and help achieve sustainable transport targets. They can also provide car clubs with access (whether dedicated or not) to local authority-managed parking, frequently although not always on-street.
- **Department for Transport (DfT), Transport Scotland**: These are less focused on local transport issues than local authorities, although still motivated to understand how car clubs can achieve national sustainable transport targets.
- **Metropolitan Area Transport Authorities**: These are known as passenger transport executives in the UK (e.g. Transport for London (TfL); Transport for West Midlands (TfWM); Transport for Greater Manchester (TfGM)) and do not typically provide physical space to car clubs for vehicle parking. They play a key role in co-ordinating transport provision in most of Britain's largest conurbations/metropolitan areas.
- **CoMoUK**: This is a charity focused on shared mobility services, including car clubs. CoMoUK has a track record of extensive surveying of car club operators and users and the maintenance of associated data.
- **BVRLA**: The British Vehicle Rental & Leasing Association (BVRLA) is the UK trade body for companies engaged in vehicle rental, leasing and fleet management, including some car club operators (Zipcar, Ubeeqo, etc.)

Where can I find further information about car clubs and their impacts?

Recent detailed literature reviews can be found in:

- Shaheen et al. (2015): Shared mobility: definitions, industry developments and early understanding.
- Ferrero et al. (2018): Car sharing services: an annotated review.
- Lagadic et al. (2019): Can car sharing services be profitable? A critical review of established and developing business models.
- Shaheen et al. (2019a): Shared Mobility Policy Playbook.
- Shaheen et al (2019b): Sharing Strategies: car sharing, shared micromobility (bike sharing and scooter sharing) and innovative mobility modes.

The academic journal *Transportation* published a 2015 special issue about the impacts of car clubs.

The University of California, Berkeley Transportation Sustainability Research Center[3] and Innovative Mobility Research Group[4] maintain an online library of their extensive work on shared mobility.

CoMoUK's UK-focused research, including their historic annual survey publications beginning in 2007, is available on their website[5].

Other resources include the (international) Carsharing Association, the Shared-Use Mobility Center, the pioneering Canadian service Communauto's Frenchlanguage bibliography (with studies from the 1970s and earlier; see Communauto (2020a)), DfT (DfT, 2020) and Germany's Bundesverband CarSharing (CarSharing Association; see Bundesverband CarSharing (2020)).

The opportunities that car clubs offer to control car ownership, car use and hence transport-related emissions are highly sought after by many local authorities.

With the car club market in the UK maturing into a formidable part of the urban transport system, we have now arrived at discussions regarding better integration of car clubs with traditional travel modes (bus, rail, etc.). For example, mobility as a service (MaaS), an emerging transport concept, which aims at combining different transport modes and offering tailored mobility packages (Esztergár-Kiss & Kerényi, 2020; Shaheen & Cohen, 2019) to users, has received increasing attention recently. Because car clubs can be complementary with other transport modes, they align well with the efficiency objectives of many MaaS initiatives.

1.2 Why consider a data sharing framework?

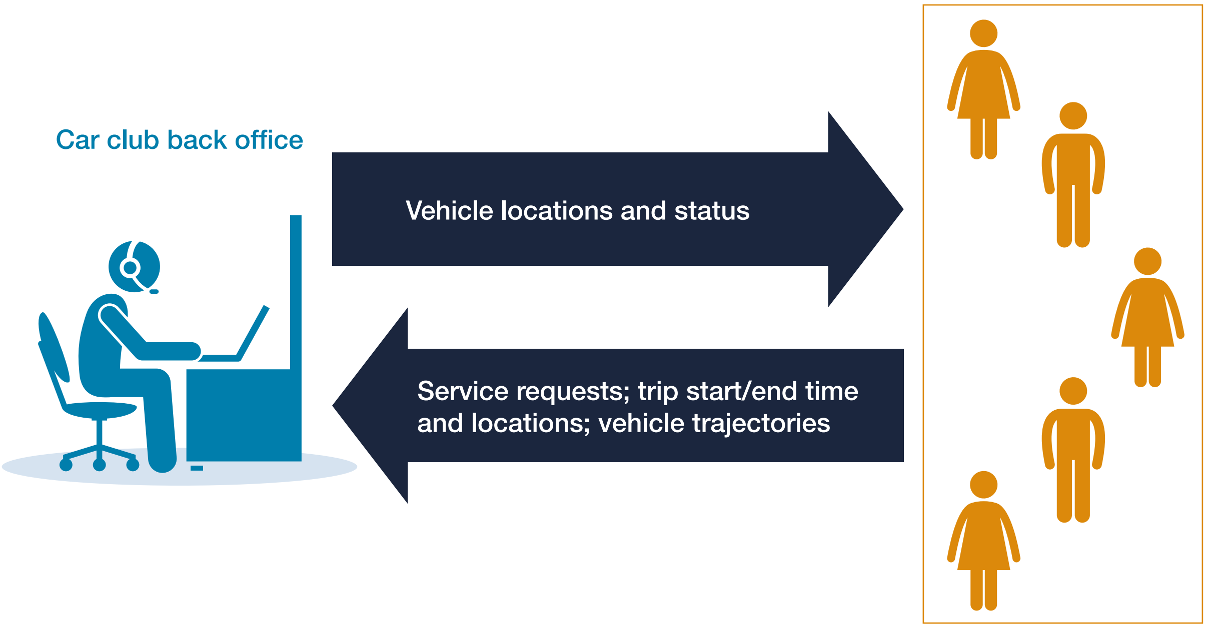
Digitisation means that data streams are increasingly generated by mundane everyday activities, which are exploited by all types of businesses to improve the value proposition they present to the customer.

3 Transportation Sustainability Research Center. Shared mobility (https://tsrc.berkeley.edu/research/shared-mobility)
4 Innovative Mobility. Shared mobility and mobility on demand (http://innovativemobility.org/?page_id=2619)
5 CoMoUK. Collaborative, fair and sustainable mobility creating better communities (https://como.org.uk/)

The transport sector is no exception, with real-time information covering traffic conditions, people-movement and vehicle trajectories being integrated by various vendors into data products that promise to reduce congestion and enhance safety.

Car clubs in particular generate highly granular data streams (see Figure 1.2 for the information exchange between operators and users) since services are highly reliant on information technologies to deliver the required customer experience; and the vehicles themselves are generally equipped with modern telematics equipment. Yet, this data is not currently used by planning authorities in the UK to understand and analyse the impacts of this travel mode. In fact, a key recommendation of the Task & Finish Group on Car Clubs appointed by the London Councils in 2019 was to develop a data sharing framework to address the lack of robust data and an evidence base in the car club sector[6].

Figure 1.2: Information flow between car club operators and users



Source: Authors' own

The urban transport sector is a complex ecosystem of private and public entities fulfilling various roles. Car clubs are typically delivered by private operators, but many of them are dependent on local authorities providing dedicated access to on-street space. For station-based car clubs, this frequently takes the form of dedicated on-street parking bays, while free-floating schemes may seek bespoke parking permits. For its part, the local authority in many cases will view car clubs as a mechanism to achieve public policy goals for managing automobile ownership and use, with little or no cost to the public purse.

6 London Councils (www.londoncouncils.gov.uk/node/36183)

This interdependence between car club operators and local authorities is at the core of the need for a data sharing framework. The motivation is that standardised data flows between them offer the possibility of increasing the efficiency of this relationship, thus creating net new value and offering a win-win opportunity as discussed further on.

In fact, discussions on data sharing are not limited to transport research. For example, OPen ALgorithms (OPAL), a project aimed at unlocking the potential of private sector data for public good purposes, have made progress in the sharing of call detail records between telecommunication operators and the public sector (OPAL, 2018).

Section 2 details key examples of data sharing within the UK's transport sector and internationally, as well as the data standards that structure the data flows.

Data from car clubs offer the possibility of helping local authorities answer the key policy questions needed to unlock further policy support. Without operational data, some policy questions are difficult to answer and others are intractable. The supply of car club services could be optimised by the local authority to ensure that public policy goals share equal footing with the usual commercial considerations of a private business. Standardised data would facilitate benchmarking against operations in peer local authorities, as well as eliminating the need for data to be specified separately in each individual contract between a car club operator and a local authority. Neither party would need to invest resources on data specification during a contract negotiation. Moreover, standardised data would enable local authorities to develop shared analytical tools or scripts, especially for common goals, such as promoting greener transport. There are significant economies-of-scale advantages to such shared tools.

Despite these potential benefits, implementing a common data sharing standard is a non-trivial task. Key concerns from the perspective of car club operators include:

- confidentiality of proprietary data, including compliance with legal requirements and possible compromising of market position;
- ownership of data and data standard, including whether highly disaggregate data shared with a local authority's transport officers would then become fully public information, available to any member of the public (or competitor);
- need for significant software development in the operator's back-end systems to extract the desired data (data is available in a wide variety of forms and formats, in keeping with the variety of system architectures adopted by the operators; unless there is a guarantee that the structure of the data they are required to share will not keep changing, there is a reluctance to invest in software development);
- capability of local authority partners to adequately manage, draw value from and store shared data, which would need to be a sustained (not one-off) commitment;
- their shared data being used against them; for instance, shared data could document the precise set of operations during a service disruption that would technically violate an agreed undertaking, but which is de minimis and would be convenient for all concerned to neglect;

- ultimately, the benefits of sharing data can appear speculative from the perspective of an operator, whereas the risks are concrete. Without firm knowledge that data sharing is an industry standard and required of all operators, an individual operator interacting with an individual local authority could rationally conclude that the costs outweigh the benefits.

As we shall see, in many instances, existing contractual practices both in the UK and abroad do not include detailed data sharing protocols. We also report great diversity in the nature of data provided by car club operators; these points are covered in detail in Table 3.1, Section 3.

1.3 Aim and scope

For the reasons just described, the objective of this research is to propose a data sharing framework between the car clubs and local authorities in the UK, which maximises the potential benefits, while minimising the downsides. In designing the Car Club-Local Authority Data Standard (CLADS) data sharing framework, we carefully reviewed the existing data sharing frameworks for shared mobility services in other countries and sought frank input from representatives of local authorities in London, car club operators and transport planning experts both within the UK and abroad.

This document focuses on the contents, level of granularity and frequency of data provision. Second-order considerations of data sharing, the design of the data management IT system, the data repository and data anonymisation are outside the scope of this initial proposal of the data format and will be addressed in due course by the stakeholders involved in developing CLADS.

1.4 Research Approach

The development of the CLADS proposed data standard comprised three related workstreams:

- a scan of the relevant literature, including the existing data sharing frameworks for shared mobility services and their applications in the real-world (summarised in Section 2);
- semi-structured interviews with leading practitioners internationally, focusing on their current data sharing arrangements with both car clubs and other forms of shared mobility (e.g. taxis and bike sharing; Section 3);
- in-person expert workshops, with car club operators, local authorities and other interested parties, when drafts of the data sharing framework were discussed in detail (Section 4).

Section 5 then formally presents the proposed CLADS data sharing framework and Section 6 presents examples of numerical analyses that CLADS data can support.

Finally, Section 7 highlights the next steps along with opportunities to extend the CLADS framework and Section 8 sums up and concludes.

2. Background on data sharing frameworks, platforms and regulations

Establishing the current state of play for related data standards was the starting point of this effort. In this section, we review data sharing and shared data standards developed and used in public transport and shared mobility.

We limit our review to downstream platforms and standards, which are targeted at making data available for analytics and provisioning journey planning systems. There are also several upstream platforms, such as NeTEx, NEPTUNE, TransXChange and NOPTIS, which are much wider in scope and intended for use in back office use cases under which the data is generated, refined and integrated (requiring the exchange of additional elements used to construct the timetable)[7].

7 For more information about the upstream standards and platforms, see the Transmodel NeTEx -EPTIS (www.transmodel-cen.eu/wp-content/uploads/sites/2/ITS-WorldCongress-2015.pdf) and NeTEx (www.normes-donnees-tc.org/wp-content/uploads/2015/10/NeTEX-examples_guidelines_explanatory_materials.pdf).

Therefore, the specific frameworks reviewed are:

- Data sharing frameworks:
  - General Transit Feed Specification (GTFS) (GTFS, 2020);
  - General Bikeshare Feed Specification (GBFS) (North American Bikeshare Association, 2020);
  - Mobility Data Specification (MDS) (Open Mobility Foundation, 2020);
  - Ridesourcing regulatory information platform in China (RRIP-C)[8];
  - Car club data sharing standard in Milan, Italy[9].
- Data sharing platforms:
  - TfL's open data (TfL, 2020);
  - Communauto open data (Communauto, 2020b);
  - New York Taxi and Limousine Commission's protocols (New York City Taxi & Limousine Commision, 2020);
- Data sharing regulation:
  - Multimodal travel information service (MMTIS) (European Commission, 2020)

Each of these frameworks is discussed individually, with an overall synopsis at the end of this section.

2.1 General Transit Feed Specification

GTFS provides public transit operators with a data sharing standard. It was developed in 2005 by TriMet (Tri-County Metropolitan Transportation District of Oregon), the transit provider in Portland, Oregon. The initial intention of formulating the GTFS was to enable Portland's transit schedules to be incorporated into Google Maps and GTFS was originally called *Google* Transit Feed Specification. As more agencies began to use this standard, GTFS changed its name from *Google* Transit Feed Specification to *General* Transit Feed Specification in 2009. As of July 2020, GTFS has been employed by 1,252 providers in 674 locations worldwide.

GTFS is a collection of at least 6 and at most 13 text files (also called tables). The main contents of the tables are summarised in Appendix 1. GTFS is limited to scheduled information and does not include real-time information. To overcome this limitation, an updated version of GTFS, called GTFS Realtime, was published in 2012.

GTFS data has been used widely in academic research, including for travel demand forecasting (Puchalsky et al., 2011), public transport system performance evaluation (Hadas, 2013) and accessibility analysis (Bok & Kwon, 2016; Guthrie et al., 2017; Painter et al., 2018; Wessel et al., 2017), as well as timetable generation. Notably, GTFS data only report scheduled public transit information, so some researchers have integrated GTFS with real-time data sources to obtain better results. Examples of such studies include Wessel et al. (2017) and Gaudette et al. (2016), with the first focusing on average accessibility to jobs in Toronto and the second focusing on public transit microsimulation.

8 Yang (2019), personal communication
9 Sevino (2020), personal communication

2.2 General Bikeshare Feed Specification

The GBFS is an open data standard for bike sharing operators to release *real-time* data. It was announced in November 2015 by the North American Bikeshare Association and it is still under the Association's leadership. At the time of writing this report, the GBFS has been employed by 273 cities around the world.

The main contents of the GBFS data standard include requirements on the overall bike sharing system, stations and bikes. Detailed descriptions of the GBFS are presented in Appendix 2. Compared with the MDS (Section 2.3), the GBFS requires data on station status, system operational hours and days. The most important difference is that the GBFS does not require trip and policy information. It only requires operators to report the status of stations and bikes. This is similar to the Parisian data sharing standard for micromobilities; it might be a way of protecting users' privacy compared to the trip-level data in the MDS.

Since the GBFS was announced much later than the GTFS, it has only been used by a handful of studies compared to the GTFS. Couch and Smalley (2019) obtained data from all bike sharing operators in the USA releasing GBFS feeds, especially information on the geographical co-ordinates of bikes or docks. The data was used for the equity analysis of docked and dockless bike sharing systems. Pandey et al. (2018) combined the station status of Citi Bike (published according to the GBFS) with Citi Bike's operational data and worked on bike sharing system design (station capacities and occupancies) and big data collection and analytics tools, respectively. Lam et al. (2019) applied bike sharing data to unusual events detection. The bike sharing station data collected followed the GBFS standards. Haveman et al. (2019) provided a functional design of a tool for communications between MaaS providers and transport operators; the static information of transport operators is shared with MaaS providers according to the GBFS standard.

2.3 Mobility Data Specification

The MDS was inspired by the GTFS and GBFS (Sections 2.1 and 2.2). It was designed for *real-time* data sharing between general shared mobility services (i.e. bike sharing, scooter sharing, ridesourcing, etc.) and regulatory agencies.

The MDS was originally created by the Los Angeles Department of Transportation in 2018; stewardship of the MDS and ownership of the repository was transferred to the Open Mobility Foundation in November 2019.

As of February 2020, the MDS has been adopted by more than 80 cities globally, including Los Angeles, Santa Monica and Austin. Several major European cities (e.g. Lisbon, Milan) are considering implementing the MDS in their data sharing protocols with shared mobility operators. London is also piloting the MDS for bike sharing services. Detailed contents of the MDS are summarised in Appendix 3.

The MDS provides three application programming interfaces (APIs) for different stakeholders:

- The provider API: This is intended to be implemented by mobility providers and consumed by regulatory agencies. When a municipality queries information from a mobility provider, the provider API has a historical view of operations in a standard format.
- The agency API: This is intended to be implemented by regulatory agencies and consumed by mobility providers. Providers query the agency API when events such as the start of a trip or vehicle status change occur in their systems.
- The policy API: This is intended to be implemented by regulatory agencies and consumed by mobility providers. Providers query the policy API to get information about local rules that may affect the operation of their mobility service or which may be used to determine compliance.

The main data fields required by the MDS include: vehicle information; vehicle status; trip information; and policies applicable to the shared mobility services. For trip information, all possible Global Positioning System (GPS) co-ordinates collected during shared mobility trips are required.

We only found two published research studies discussing the MDS. D'Agostino et al. (2019) pointed out the risk of having real-time GPS data in the MDS. GPS data can potentially disclose an individual's identity, meaning that there is a risk of exposing the rider's personal travel information when individuals travel from identifiable locations (e.g. home to work). Hence, some level of trip aggregation may be necessary to address privacy concerns. Baltra et al. (2020) argued that not only the MDS but also the GBFS has a high risk of disclosing user privacy. The authors proposed an algorithm and argued that their algorithm can better protect user privacy without sacrificing the usefulness of the data.

2.4 Ridesourcing regulatory information platform in China

The RRIP-C was created by the Ministry of Transport of China in 2016. It was intended to regulate the *real-time* data sharing between ridesourcing companies (also referred to as ridehailing companies; see Section 1.1. for clarification of terminology) and regulatory agencies. All ridesourcing operators operating in China are obligated to follow the RRIP-C.

The RRIP-C has three levels of data: national-level; province-level; and city-level. Operators that operate in more than one city are required to upload data directly to the national-level platform; the national-level platform then sends instructions to the operators according to the data they receive, such as system scale, system operation, customer satisfaction and the scale of ridesourcing service in the entire city. Operators that operate in only one city share data with the city-level platform according to the national-level standard; the city-level platform aggregates data from such operators and sends the data to the national-level platform.

Once the data is received, the national-level platform sends instructions to the city-level platform and the city-level platform instructs the operation of the ridesourcing service according to the instructions from the national-level platform.

The main contents of the RRIP-C are summarised in Appendix 4. When compared to the MDS, the main contents of the RRIP-C are generally similar. One major difference is that the RRIP-C requires more detailed information about drivers (which is also the case with the New York City Taxi and Limousine Commission; see Section 2.8) as well as passengers. Detailed information about drivers and passengers have benefits for the regulation of the services, especially the personal safety considerations of both drivers and passengers and ease of tracing suspected COVID-19 carriers. However, it raises concerns regarding the privacy of the operators and users. Another difference is that the RRIP-C does not require parking information. This is because this platform was designed for ridesourcing services only, whereas the MDS targets a wider range of shared mobility services.

2.5 Car club data standard: Milan

Data sharing between car club operators and the Municipality of Milan started as early as 2013. The data sharing standard is compulsory for all operators running their business within the territory charged by the Municipality of Milan. The data sharing standard underwent two rounds of piloting in 2013 and 2017; the most recent version was published in December 2019. The data standard was designed for car clubs but we gathered that other shared mobility services also follow similar standards in Milan.

Milan's data sharing standard is designed mainly for static data sharing, with monthly updates. Operators are obliged to update user information, legal entity user information, vehicle information, trip information within ten natural and consecutive days after the reference month (see Appendix 5 for detailed items of the required data feeds). However, the vehicle location information (for both parked and in-use vehicles) is updated in real time. Car club operators in Milan are also required to share their customer satisfaction survey results with the Municipality of Milan; the survey frequency is subject to agreement with the Municipality of Milan.

2.6 Transport for London open data

As one of the largest public transport authorities globally, TfL delivers 7 million bus journeys and 5 million underground train journeys daily, while overseeing more than 21,000 London taxis and more than 88,000 private hire vehicles.

TfL launched its open information initiative in 2007. Any interested app developer who wishes to provide transport information to customers can access it. TfL also collaborates with app developers on the design of the TfL APIs to maximise the value created by the data.

TfL's data is available on its website as well as the London Datastore[10]. Information that is shared in the open data include:

- London Underground:
  - tube timetable data;
  - train prediction service, station and line status, updated every 30 s;
  - Tube this weekend (planned line and station closures for the coming weekend), updated every 720min.
- Bus, coach and river:
  - live bus and river bus arrival (updated every 30 s);
  - bus stop locations and routes (updated every week);
  - coach parking sites/locations (updated every 1,440 min);
  - pier locations (updated every 1,440 min).

Other than this live public transport service data, TfL also has open data on road traffic, walking and cycling, air quality, etc.

2.7 Communauto open data

Communauto, North America's oldest car club, which currently operates in 15 Canadian cities and Paris (France), declares that it "makes its data available to everyone in the hope that they can contribute to the development of sustainable transport" (Communauto, 2020b). It has a long-established history of providing operational data to academic researchers (El Fassi et al., 2012; Habib et al., 2012; Morency et al., 2012; Wielinski et al., 2019).

Communauto has posted station information (ID, sector, zone, latitude/longitude) for nine cities on their website (Communauto, 2020b) in the XML format. However, their current data sharing framework does not include information regarding shared vehicles and trips.

2.8 New York Taxi and Limousine Commission

New York City's Taxi and Limousine Commission has been providing trip-level data for all their taxis since 2009. More specifically, yellow taxi data has been open since 2009, green taxi[11] data has been open since 2013 and for-hire vehicles since 2015. All data is in text format and can be downloaded for free from the Taxi and Limousine Commission website. Yellow and green taxes share more detailed information, including pick-up time, pick-up and drop-off zones, number of passengers and fare information. For-hire vehicles only provide pick-up/drop-off times and locations.

10 London Datastore (https://data.london.gov.uk/)
11 'Green taxis' in New York City operate outside the central business district; 'yellow taxis' are not restricted in this way.

2.9 Multimodal travel information services regulation

The MMTIS regulation was published by the European Parliament in May 2017. It is not a data sharing framework as such but a delegated regulation, which aims to open services operating on public contract data to the public and establish national access points for the data.

The Annex of the MMTIS regulation lists a number of data categories that data providers are required to share, which are presented in Appendix 6. Both static and dynamic data requirements are listed, and there are three levels of data sharing for each type of data. Car club information, together with information on other shared mobility services, is in level 2 for both static and dynamic data. Level 2 static data asks for car club stations and level 2 dynamic data asks for car club vehicle availability.

The process of opening mobility data is still in the early stages. The timetable in the regulation for Member States implementing the data opening states that Member States should achieve level 1 static data by 1 December 2019, level 2 static data by 1 December 2021 and level 3 static data by 1 December 2023. The timetable for dynamic data opening has not been regulated yet. Hence, there is still a long way to go for the European Union (EU) to have a regulated data sharing for car club operators and local authorities.

2.10 Summary

This section introduced a range of data sharing frameworks currently in use. A summary of the main features of the data sharing framework is presented in Table 2.1.

Key takeaways from this review are:

- **Data sharing frameworks mostly have a common structure**. The level of detail varies depending on the type of transport service and the level of ambition for the use of the data.
- **We should aim to build a data sharing standard for real-time data**. Among the nine data sharing standards/regulations, the MDS, GBFS and RRIP-C support real-time data sharing. The GTFS, data sharing standard in Milan and MMTIS are not designed for real-time data in the first instance, although they are aiming for real-time data sharing in the future.
- **Care should be taken to balance the usefulness of the data and user privacy**. Although real-time data sharing frameworks are increasingly prevalent, GPS tracking data has a high risk of being used to identify individual users. Hence, the level of granularity of the trip data should be carefully determined by discussions with both local authorities and car club operators. If real-time data is needed, different levels of data access are advisable. For example, the general data user can access only customised synthetic data and only those with special requirement can access real-time raw data (Young et al., 2019). It is also worth noting that several cryptographical and technological developments are also currently underway to support raw data sharing while preserving privacy (Domingo-Ferrer & Blanco-Justicia, 2020; Zhang & Lin, 2018).

Table 2.1: Summary of data sharing frameworks

Name	Travel mode	Format	Main contents	Year published	Coverage
General Transit Feed Specification (GTFS)	Public transit.	CSV.	Agency, routes, trips, stops, fare, transfer information and operational hours.	2005	674 locations worldwide.
New York City Taxi and Limousine commission	Taxi/ridesourcing.	CSV.	Trips and driver information.	2009	New York City.
Car club data standard: Milan	Car club.	CSV or spreadsheet.	Operators, vehicles, trips and user information.	2013	Milan, Italy.
General Bikeshare Feed Specification (GBFS)	Bike sharing.	JSON.	System, stations, bikes, pricing and operational hours.	2015	273 cities worldwide.
Ridesourcing Regulatory Information Platform in China (RRIP-C)	Ridesourcing.	JSON/protocol buffer.	Operators, vehicles, trips, drivers and passengers	2016	China.
Multimodal Travel Information Services (MMTIS) regulation	Public transport and shared mobility.	N/A	Public transport: network typology, timetable, operational calendar. Shared mobility: stations, refuelling stations, service information, fare, vehicle availability.	2017	EU.
Mobility Data Specification (MDS)	Shared mobility (but mainly used by micromobilities).	JSON.	Systems, business areas, trips, GPS trajectories, vehicles, policies and operational hours.	2018	More than 80 cities worldwide.
TfL open data	Public transport, walking and cycling, traffic data, air quality, etc.	JSON.	London Underground: timetable, train prediction service, station and line status, Tube this weekend. Bus, coach and river: arrival, bus stop locations and routes, coach parking sites/ locations, pier locations, weekly bus performance report.	2007	London.
Communauto open data	Car club.	XML.	Car club station location.		Montreal, Gatineau and Sherbrooke, Quebec; Ottawa and Kingston, Ontario; Southwestern Ontario; Halifax, Nova Scotia; Paris (France).

Source: Communauto (2020b), (European Commission, 2020), GTFS (2020), New York City Taxi & Limousine Commission (2020), (North American Bikeshare Association, 2020), Open Mobility Foundation (2020), TfL (2020), (Sevino, 2020), and (Yang, 2019)

3. Interviews

To gain a better understanding of how car club data is currently being shared between car club operators and local authorities around the world, we surveyed one organisation (Polis Network) and eight cities (New York, Los Angeles, Milan, Paris, Amsterdam, Bremen, Beijing, and Shanghai).

The full set of interview questions is presented in Appendix 7. Each interview generally followed the same sequencing of questions, with minor adjustments according to the current car club data sharing situation in each city.

3.1 Polis Network

Polis Network is the only organisation we surveyed; it is a leading network that aims to develop innovative technologies and policies for local transport within European cities and regions. The main lesson learnt from the survey is that the EU has plans to ensure that all the Member States open up their mobility data and build a national data access point. The MMTIS regulation was passed in 2017; travel modes, specific data items and the timetable for carrying out the data opening are provided in the Annex of the commission delegated regulation.

According to the requirements of the MMTIS, Member States should have made their 'level 1' static travel data (static information of public transport services) available by 1 December 2019. However, the process was not yet complete at the time of survey. The national data access points where Member States store their data are also under construction.

We also learnt that ridesourcing data is not readily shared in the EU, largely due to the relationship between local authorities and ridesourcing operators. We gathered that in addition to privacy and propriety concerns, an important reason why ridesourcing data is not commonly shared is because local authorities do not have much power in their equation with the ridesourcing operators. For example, ridesourcing is regulated at the national level in the Netherlands and at the regional level in Belgium. Ridesourcing in the UK is regulated at the local authority level; however, drivers can obtain their licence from one local authority and then operate in a different area. Thus, it is difficult for local authorities to know the exact state of ridesourcing operations within their jurisdiction.

3.2 Cities

New York City and Los Angeles are the two American cities we surveyed.

New York City has one of the most established shared mobility data sharing frameworks across the USA. As noted in Section 2, New York City instituted data sharing with taxis as early as 2009 and for-hire vehicles since 2015. For car club data, they launched a two-year data sharing pilot with car club operators in June 2018. They selected 14 neighbourhoods in New York City; car club operators (Zipcar and Enterprise) operating in these neighbourhoods are required to share trip-level data with the City on a quarterly basis. The City's primary motivation for launching this data sharing pilot was to better understand how public kerbside space is being used.

Los Angeles is the city where the MDS was first established. However, Los Angeles only has some basic information from car clubs (trip start/end, travel distance, travel time, etc.) not the detailed information that the MDS requires. In fact, the MDS has not been applied to car clubs in Los Angeles as yet because of a change in legislation. Car club operators cannot record 'during the trip' data; however, the MDS requires real-time GPS data. Hence, they are still in the process of revising the data requirement for car clubs.

Milan, Amsterdam, Paris and Bremen are the European cities we surveyed. Among these four cities, **Milan** has the most well-established data sharing with car club operators (see Section 2.5 and Appendix 5 for details). The current data sharing framework only requires operators to share real-time vehicle status, with the rest of the data being static. Interviewees indicated that they are heading towards a fully dynamic data sharing framework and are studying the MDS as a potential option.

Paris and **Amsterdam** did not have data sharing with car clubs at the time of our interviews, but they have data sharing with micromobility service operators. Paris currently has data sharing with e-scooters, mopeds and free-floating bike sharing services. Amsterdam only has data sharing with e-scooters; they do not have bike sharing in the city. Free-floating micromobilities in Paris are required to share their location and status (when in use or free) to the local authorities every 3 h.

Bremen (Schreier et al., 2018) is a very special case amongst the cities we surveyed. Bremen has many narrow historical streets that lack available space for car parking. The City is developing infrastructure to support active modes, public transport and shared mobility to reduce car ownership, and believe they have been very successful in terms of car club activity. By the end of 2019, the number of active car club members in Bremen reached 20,000 out of a population of approximately 570,000. The overall satisfaction level of car club users is very high (93% happy with the booking process, 81% with vehicle availability and 84% with the station accessibility; see Schreier et al., 2018). When asked about data sharing protocols, interviewees in Bremen revealed that they do not have formal data sharing contracts with car club operators to receive their operational data. Instead, operators share their annual survey on user satisfaction and operators and local authorities interact on a regular basis to discuss how to best serve users and make car clubs more successful in Bremen.

Beijing and **Shanghai** are the two Asian cities we surveyed. China has a well-established data sharing framework for all ridesourcing companies operating in China, as summarised in Section 2.4. Neither of these two cities currently has a data sharing agreement with car club operators. The interviews revealed that the main reason for this is that car clubs are too small-scale to have an impact on traffic. However, ridesourcing has induced more traffic congestion and competes with taxis and public transport. Hence, they deem it more important to understand the ridesourcing data.

In fact, when interviewees from the cities without a current car club data sharing arrangement were asked whether they plan to establish formal data sharing with car club operators in the future, all replied in the affirmative with the exception of interviewees from the two Chinese cities. The primary reason is as noted in the preceding paragraph: the car club market in these two cities is small and they expect the market to further shrink in the future. When asked about their perspective on the shared mobility market in general, the opinion was that the market will remain at a similar scale over the next few years. Their attitude towards shared mobility appeared relatively neutral: they neither support nor discourage the market because supporting public transport is their priority and they do not want the fleet size of shared mobility services (especially ridesourcing) to escalate. Additionally, ridesourcing competes with traditional taxis and interviewees from the two Chinese cities identified this as a politically sensitive issue.

The planning agency in Paris was also concerned about fleet sizes but their attitude to the car club market was more proactive. In fact, all cities we surveyed in the USA and Europe were optimistic and positive about the growth of the car club market. The only exception was the Polis Network, who were relatively cautious in their forecast. Their main concern was that if it continues to be easy to maintain a private vehicle, and if other shared mobility modes become very cheap and easy to use, then the car club market will not take off.

3.3 Summary

Formal data sharing, with a legal contract between car club operators and local authorities, was not common at the time of writing of this report. Table 3.1 presents a summary of our findings from the international interviews.

For cities with car club data sharing (formal and informal), the data is provided in relatively simple terms (monthly or quarterly, shared in text format) without formal IT systems and APIs updating the data in real time. The extent of data shared ranges from basic (Los Angeles) to very detailed (Milan).

For cities without car club data sharing, the US and European cities are in the process of establishing data sharing frameworks, which is partially due to their optimistic views of the car club market. On the other hand, the Asian cities we surveyed were more pessimistic about the market and hence do not consider car club data to be a priority.

Beyond formal data sharing, frequent interaction between operators and local authorities can be very helpful, especially in smaller cities like Bremen.

The existing data sharing frameworks, while loosely based on the MDS, have all been independently developed and tailored to local conditions.

Table 3.1: Summary of car club data sharing experiences around the world

City	Area and population	Number of car club operators	Formal/ informal data sharing with car club operators	Formal/informal data sharing contract with other modes of shared mobility	Car club data sharing format	Contents	Update frequency	Priorities	Plans for formal car club data sharing framework
Amsterdam	219.3 km^2, 8.73 million (2019)	3	No.	Formal (with e-scooters and taxes).	N/A	N/A	N/A	Distribution of shared mobility vehicles; pricing strategies to reduce private car travel in city centre.	Yes.
Beijing	16,410.5 km^2, 21.54 million (2019)	4	No.	Formal (with ridesourcing and ride sharing).	N/A	N/A	N/A	Congestion.	No.
Bremen	325.42 km^2, 5.70 million (2019)	3	Informal.	Informal (with bike sharing).	N/A	Annual survey on customer satisfaction; information exchange.	At least every quarter.	Reducing car ownership.	No.
Los Angeles	1,215 km^2, 3.99 million (2018)	2	Informal.	Formal (MDS standard with bike sharing and e-scooters).	Excel sheet (XLSX).	Trip start/end, location, travel distance, travel time.	Quarterly.	Use of public space.	Yes.
Milan	181.67 km^2, 1.40 million (2018)	5	Formal.	Formal (with all shared mobility modes).	Excel sheet or CSV.	User information; operator information; vehicle information; trip records.	Monthly.	Reducing car ownership.	Will continue on to a dynamic data sharing framework.
New York	1,214.4 km^2, 8.40 million (2018)	3	Formal (a two-year pilot since mid-2018).	Formal (with ridesourcing, car clubs, bike sharing and ride sharing).	CSV.	Trip records.	Quarterly.	Use of public parking space.	To be accessed post-pilot.
Paris	105.4 km^2, 2.15 million (2020)	7	No.	Formal (with free-floating e-scooters and bike sharing).	N/A	N/A	N/A	Fleet size of free-floating vehicles; use of public parking space.	Yes.
Shanghai	6340.5 km^2, 24.28 million (2019)	2	No.	Formal (with ridesourcing and ride sharing)	N/A	N/A	N/A	Congestion.	No.

Source: Personal communication with interviewees

4. In-person workshops

After the international review of existing practice, we held three workshops with local authorities in London, car club operators and third-party experts in that order.

The structure of the workshops was similar: the background of the project was presented to the attendees, followed by presentation of the draft CLADS data sharing framework and finally an open discussion focusing on the details of the data standard. After each workshop, we summarised the comments from the attendees and revised the CLADS framework.

4.1 Workshop with local authorities

The first workshop with local authorities in London was held on 4 February 2020; representatives from 17 London Boroughs participated.

The draft CLADS data sharing framework we presented during this workshop was primarily based on what we learnt from the existing data sharing frameworks (see Section 2). The main structure was derived from the MDS and was adapted to the specifics of car club operations in the UK (for example, including details of the parking locations). The intent was to build a very comprehensive data sharing framework that is not only applicable to different types of car club services, such as RT and free-floating car sharing (FFCS) but is also compatible with other types of shared mobility services.

The first version of the data sharing format consisted of 12 data files. It was designed for real-time data sharing, with JSON (JavaScript Object Notation)[12] as the recommended data format. The contents of the first draft included regular data on vehicles, stations and trips, as well as data on business hours, cost structures, policies applicable to car clubs and system alerts.

At the workshop, participants noted that the data sharing framework included far more information than was necessary and were concerned about information overload. The essential requirements were identified to be as follows:

- **Data consistency:** Participants indicated that they would greatly value consistency in the format of data provided by different operators to the various boroughs. This would enable the boroughs to compare the effectiveness of their policies and learn from each other.
- **Data transparency:** Participants also indicated that transparency in the processing of data that is delivered to them is essential. Where appropriate, they would prefer to receive the data in a format that they can process uniformly and consistently. For example, local authorities currently find it difficult to compare car club vehicle use across different operators and across local authorities since operators follow different definitions of 'vehicle use' and share only the processed outputs. By sharing unprocessed data with commonly agreed definitions and using shared data processing algorithms/tools across boroughs, it should be possible to achieve consistent computation of car club vehicle use statistics.
- **A dashboard for processed data:** While raw data and transparency of the methods used for processing the data are important, local authorities also admitted that data processing was burdensome. They would prefer processed outputs where there is no ambiguity, such as gender balance of users. On exploring this issue further, it was clear that raw data from the operators would provide the most transparency and local authorities would need to invest a one-time effort into setting up a dashboard based on their requirements. The establishment of a standard data sharing framework is further conducive to this effort.
- **Public benefit:** Local authorities would ideally like to feel that they are working with the operators, rather than against them, towards demonstrating the public good of shared cars, that is, to ultimately reduce car ownership, improve air quality, etc.

Clearly, real-time GPS tracking will generate huge amounts of data that is not easy to process and archive. Additionally, GPS tracking data together with detailed user information data may violate privacy regulations. Workshop participants reached the conclusion that the operational details of car clubs are not essential for well-informed policy decisions. However, real-time operational data would be useful for enforcement purposes.

The Lower Layer Super Output Area (LSOA) (Ministry of Housing, Communities and Local Government, 2020) was identified as the preferred level of spatial granularity for member/user locations to balance the need for details against concerns of privacy. A quarterly update frequency was generally considered to be sufficient from the perspective of the local authorities, which is in keeping with the best of the many practices across local authorities.

12 Introducing JSON (www.json.org/json-en.html)

Based on the feedback from the first workshop, we made substantial changes to produce the second draft of the data sharing framework:

- The number of required data files was reduced from 12 to 4, eliminating real-time GPS and operational data. RT operators would share user, vehicle and trip information while FFCS operators would share all these files plus a vehicle distribution information file.
- The address of the user, trip origin/destination and vehicle distribution information were aggregated to LSOA level rather than point co-ordinates.
- The update frequency was changed from real-time to every quarter. Since FFCS vehicle distribution is very volatile, we retained hourly updates for FFCS services.
- The user information file was pared down to protect user privacy and included member ID, age, sex, car ownership and membership of other types of car club services, if applicable.
- The data sharing format was changed from JSON to CSV/XLSX spreadsheets.

4.2 Workshop with car club operators

The second draft of the data framework was presented at the second workshop with the car club operators on 13 February 2020. Four major car club operators in the UK (Co-wheels, Enterprise, Ubeeqo and Zipcar) participated in the workshop.

The lack of a consistent data sharing framework is, from the operators' perspective, cumbersome since they need to deal with a huge variety in the type of data requests from the local authorities. Therefore, operators were generally supportive of the data sharing framework as being potentially beneficial to all involved and indicated general comfort with the draft CLADS framework. While the operators were clear that data sharing would be subject to non-disclosure of commercially sensitive operational details, the draft CLADS framework was considered to be appropriate.

The main issues discussed at the workshop were as outlined below:

- **Limitations in data available to be shared:** User information, such as sex and car ownership, is typically not available to the operators. The only sociodemographic data available to them is age (from the driving licence records) and perhaps consumer classification from commercial sources, such as Acorn (Acorn, 2013).
- **Concern for user privacy balanced against analysis needs:** The user's unique member ID from an operator's back-end systems cannot be shared due to privacy concerns. An anonymised member ID can be provided, but it will be necessary to ensure continuity in the use of member IDs across different reporting periods. This is necessary for the local authorities to identify frequent users and their use patterns over a year or longer. However, this will involve some development work to the operators' back-end systems. Operators also expressed concern about such a user ID potentially violating data privacy regulations; this will need to be considered

carefully in drawing up the data sharing contract. Operators also suggested that age could be reported as age bands to address data privacy concerns.

- **Different user types:** The operators pointed out that private and corporate users must be treated differently; since both are important to the local authorities, the data standard must be modified to accommodate these differences. Also user information for corporate users must be treated carefully, as they are likely to be interpreted differently by different corporate entities.
- **Different service types:** The CLADS framework was designed to accommodate both RT and FFCS services; however, the differences in the kind of data available for each of these services was not obvious to the project team until the discussions at the operators' workshop.
- **Operational hurdles:** For RT car club services, the vehicle and parking bay (station) are not a one-to-one match. Shared vehicles may be relocated to other parking bays or taken out of service for various reasons, such as maintenance. It is also possible that a single parking bay is used for more than one vehicle, depending on the length of the bay.
- **Usefulness of trip details:** While details of car club vehicle trips, such as the timing and location of stops, would no doubt be of interest to planning agencies such as TfL, privacy considerations make this a difficult issue to resolve. Given that local authorities do not have need for data at this level of detail, it was agreed that aggregate vehicle trip data would be provided for each trip, such as total mileage and total actual driving time.

We then made minor changes to the draft data sharing framework based on the issues discussed:

- We removed sex, car ownership and membership of other types of car club in user information and added socioeconomic class as optional.
- We removed the 'Fleet Information' file and used 'Parking Bay Information' instead.
- We modified the 'Parking Bay Information' file to include the number of vehicles and the details of the vehicles assigned to each parking bay during the reporting period, capturing, for example, when one vehicle is replaced by another for maintenance reasons.
- We split the trip information file into separate formats for RT and FFCS services and included aggregate trip details (mileage, driving time).

4.3 Workshop with third-party experts

The revised version of CLADS was presented to the third-party experts who attended the third workshop on 13 March 2020. Attendees included academics, representatives from CoMoUK and BVRLA, independent domain experts and representatives from TfL and DfT.

In addition to several minor comments, the discussion centred around two issues: one regarded the practicalities of making such a data standard operational, in particular the contractual and legal necessities; the second issue was the trade-off between the degree of spatial aggregation and the value of the data. The attendees of this workshop argued for more spatial granularity than the LSOA, especially for regions outside dense conurbations like London where the average LSOA can be very large. There was also discussion around the feasibility of going with latitude/longitude locations for users and their trip origins and destinations. While this is no doubt preferable to spatial aggregation, the corresponding burden on the contractual process was deemed too high, especially since the aim of this project is to produce a data standard that can be put into operation as soon as possible.

To further investigate the question of spatial granularity, after the workshop we performed a series of statistical analyses based on four levels of spatial aggregation (postcode district, LSOA, square grid of size between the average LSOA and output areas (OAs) and OAs). Population and population density across the UK were examined to determine how much information may be lost at each spatial level. It was concluded that the postcode district and grid configurations are not desirable because the postcode district is too coarse and in a square grid population and population density distribution would lack coherence. This is because the grids would cover the area uniformly, whereas OAs and LSOAs are designed based on considerations of population and geography. Also, sticking to census geographies has the advantage that the LAs can combine a large number of secondary data sources with the car club data to develop insightful analyses. For example, the Index of Multiple Deprivation (IMD), Transport Classification of Londoners (TCoL) and public transport accessibility levels (PTALs), as discussed further in Sections 5 and 6.

Comparing the geography of the OA and LSOA, the LSOA can be as large as 67,283.5 ha. On the other hand, the smallest OA is 0.02 ha, with a corresponding population of 91 people in central London. With such a small area and population, there is a high risk of inadvertently violating user privacy. Therefore, we recommend the LSOA as the basic requirement for spatial details. Finer spatial scales, such as OAs, may be provided (at the option of a contracting local authority) where appropriate.

4.4 Post-workshop engagement

We maintained an open channel of communication with the car club operators and local authorities after the third workshop, with the objective of gathering feedback from the operators regarding the ease of use of the data sharing framework and any practical considerations in applying the data standard. This has been instrumental in making a number of tweaks to the CLADS framework to make it more acceptable to the operators while not losing value from the perspective of the local authorities.

We also followed up with an additional webinar-based workshop on 17 July 2020. The aim of this webinar was twofold. First, to bring all the stakeholders together in a common forum. Second, to regain the momentum that was lost due to COVID-19. Concerns raised by participants at this webinar were mainly focused on data management, data ownership and other contractual issues rather than the content of the CLADS itself. The key point made at this webinar was the importance of ensuring that the data standard is both acceptable to the operators and adopted by the local authorities widely and uniformly. It is important to operator confidence in CLADS that local authorities do not adopt the data standard partially while requiring several other bespoke details that are different across each local authority. Operator confidence is the key to their investing the time to undertake the non-trivial task of software development to generate the data.

Several changes were made to the CLADS framework based on all these sources of feedback:

- **Separating operational data from use data:** It was decided that CLADS will specify two kinds of data files. One contains operational details and will therefore be presented at a more aggregate level subject to clear and unambiguous definitions to ensure consistency. These are the summary statistics file for all car club services and the vehicle distribution file for FFCS services. The second set of data files, which comprises the user information, parking location and trip files for RT and FFCS services, is designed to share the details of the use of the car sharing service.
- **Reduced temporal granularity in the vehicle distribution file:** Since the data in the vehicle distribution file is primarily used by the local authorities to determine how many FFCS vehicles are in the borough each day, and therefore to determine a parking charge, it was decided that requesting vehicle locations on an hourly basis was unnecessary, especially since the FFCS trip file can be processed to determine the location of the vehicles in operation at any time of day. We propose that the FFCS vehicle distribution file should contain updates regarding the vehicle locations at four time steps over each day to be compiled and shared quarterly. This is in fact consistent with the best among current practices.
- **Single reporting period for all CLADS data:** With the above changes in mind, all CLADS data will be shared once at the end of every quarter.
- **Minor changes to the CLADS data fields based on operational limitations:**
    - Operators do not track parking bays individually mostly because the service is not tied to specific on-street locations but instead the operator has permission to use a specific number of vehicle parking spots on a given street. The parking location and trip files were modified to address this.
    - The actual driving time (i.e. duration for which a vehicle is driven) of car club trips are apparently difficult to extract; this was the feedback received from four different car club operators. Therefore, it was decided to include only the start and end times of each usage episode (i.e. when the car is actually picked up) and drop the actual driving time. The actual mileage can proxy (to an extent) for the driving time.
    - For the FFCS, it was decided that the trip start and end locations could be reported at the latitude/longitude level. This then further serves to compensate for the reduction in temporal granularity of the vehicle distribution file.
    - State of charge variables were added to the trip file to accommodate the growing electric vehicle fleets among the car club operators.

The issue of data privacy also cropped up several times during the post-workshop engagement period. For instance, it was noted that a combination of vehicle license plate and specific start and end times could be used in conjunction with ANPR (Automatic Number Plate Recognition) and CCTV data to identify and trace specific individuals. These are issues to be addressed during the contractual process, as discussed further in section 7.

5. The proposed CLADS data sharing standard

The proposed CLADS data sharing standard is presented in Table 5.1, taking into account the lessons learnt during the data gathering phases of this project. One summary statistics file, and three detailed data files are required for each type of car club (RT vs FFCS). For RT car club, the detailed data files are: User Information; Parking Location; and Trip Information. For FFCS, the detailed data files are: User Information; Vehicle Distribution; and Trip Information.

As described in Section 4.4, the summary statistics and vehicle distribution files contain operational details; these are pre-processed by the operators. Therefore, it is important to develop a clear and unambiguous definition for all the variables in these files and the algorithms used to process the data. Table 5.2 presents the definitions of all the other variables in CLADS.

Table 5.1: CLADS data sharing standard

File name	Spatial granularity	Temporal granularity	Set of necessary contents	Set of optional columns
Summary statistics	Local authority.	Quarterly	Number of active members; number of members joining; number of members leaving; total number of members (active and inactive); number of on-street vehicles; average booking per trip (min); average booking per trip (miles); average use (on-street) based on 24-h day; percentage availability of vehicles; number of off-street vehicles. For each vehicle parking location: average use over the quarter.	
User information	Lower Layer Super Output Area (LSOA).	Quarterly	Operator name; LSOA; anonymised user ID; user type; age.	Socioeconomic characteristics.
Parking location (for round trip (RT) car club only)	Street address.	Quarterly; updated only if there are any changes since the previous quarter.	Operator's name; local authority; street address; parking type (local authority concession or third-party parking); number of vehicle parking spots allocated.	
Vehicle distribution (for free-floating car sharing (FFCS) only)	Local authority.	Daily (mid-morning, noon, mid-afternoon, midnight); reported quarterly.	Operator's name; number of available FFCS vehicles within the local authority; update date; update time (mid-morning, noon, mid-afternoon, midnight).	
Trip information	Street-level (for RT car club) or latitude/longitude (for FFCS).	Trips made daily; reported quarterly.	Operator's name; trip ID; user ID; licence plate number; trip start/end time and date; trip start/end location (latitude/longitude for FFCS); parking bay street address (for RT); trip length (mileage); state of charge at pick-up and drop-off plus charging episodes during trip (for electric vehicles).	

Source: Authors' own, based on interviews and workshops described in Sections 3 and 4.

Table 5.2: Variable descriptions

Field name	Defines	Files that contain the variable
Age	Age of user/member (alternatively operator may summarise into the following age bands:18–24, 25–34, 35–44, 45–54, 55–64, 65+).	User information.
Anonymised user ID or user ID	Anonymised unique user ID that can identify a specific user across reporting periods; list of all users signed up for access to the service (not limited to users who have used the service in that quarter).	User information; trip information.
Local authority	The local authority name that a specific parking bay belongs to.	Parking location.
Lower Layer Super Output Area (LSOA)	LSOA with indication of year of version.	User information, vehicle distribution, trip information.
Number of vehicle parking spots	Number of vehicle parking spots (of the specified parking type, see definition below) allocated at a given street address.	Parking location.
Number of available FFCS vehicles	Number of FFCS vehicles available within the specific local authority at the stated time and date.	Vehicle distribution.
Operator's name	Operator's name.	User information, parking location, vehicle distribution, trip information.
Parking type	Whether parking is a local authority's concession or a third-party parking.	Parking location.
Socioeconomic characteristics (optional, at discretion of operator)	Any socioeconomic details of users that the operator wishes to share (e.g. sex, occupation type).	User information.
State of charge, charging episodes (electric vehicles only)	State of charge (percentage) at times of vehicle pick-up and drop-off; charging episodes during the trip other than start and end locations, that is, when and where the vehicle was charged during the trip and how much charge (for electric cars only).	Trip information.
Street address or parking bay street address	Street address of a specific parking spot in the Parking Location file; street address of the bay from which the round trip (RT) car is picked up for the trip file	Parking location, trip Information.
Trip ID	Unique ID to identify a specific trip.	Trip information.
Trip length (mileage)	Total distance travelled (accumulated vehicle mileage) during the specific trip.	Trip information.
Trip start/end location	Latitude/longitude locations for the start and end of the specific trip, that is, where the vehicle was picked up at the start of the booking and where it was dropped off at the end of the booking (for FFCS only, not RT)	Trip information.
Trip start time and date; Trip end time and date	Start and end times and dates of a specific trip, i.e. when the vehicle was picked up by the user (not the booking start time) and when the vehicle was dropped off (not the booking end time).	Trip information.
Update time and date	Time stamp for when the FFCS vehicle location was updated (noon and midnight, every day).	Vehicle distribution.
User type	Private or corporate member.	User information.
Vehicle licence plate	The licence plate number of the car club vehicle.	Trip information.

Source: Authors' own

It must be noted that not all the variables specified in the CLADS data sharing standard may be easily assembled. For instance, the EV charging data in the Trip Information file may not be easily available for reporting and sharing purposes, depending on the back-end systems of the operator.

The CLADS data will need to be updated every quarter according to this format. The data can be shared in either XLSX or CSV format to start with, using an appropriate transfer mechanism (e.g. email, secure file transfer service) to ensure security and technological feasibility. In doing so, it will be necessary to first address some of the confidentiality issues raised in section 7 of this report. London councils are currently in discussion with various stakeholders, such as TfL and the London Boroughs, to move towards a platform-based solution that is more enduring in the medium to longer term.

Although the user information required by CLADS is limited, other information sources can be integrated with the user information to enrich local authorities' understanding of car club users. Example data sources likely to be relevant in the car club context include the IMD (Ministry of Housing, Communities and Local Government, 2019; Northern Ireland Statistics and Research Agency, 2020; Scottish Government, 2020; Welsh Government, 2020), the TCoL (TfL, 2017) and PTAL (TfL, 2015), all of which are freely available at the LSOA geography. Section 6.1 includes an example based on this type of data fusion.

6. How can CLADS data provide value to car club and local authority stakeholders?

Data is valuable only insofar as it can be beneficially applied to real-world problems.

In this instance, the problem to be addressed is the need for co-ordination between car club operators and local authorities. Only by demonstrating mutual benefits can car club operators be reasonably requested to undertake the expense and hassle of providing operational data streams in the CLADS format.

Therefore, this section presents a set of fictional but realistic situations where CLADS-compliant data would provide the evidence base to help local authorities make informed policy decisions. Co-benefits also accrue to the car club operators because local authorities that have confidence in the scale and scope of the positive impacts of car clubs will be in the best position to policy actions that support the sector's growth.

To avoid doubt, all names that appear in this section are fictional and not intended to resemble any specific individuals, operators or local authorities.

6.1 Fictional scenario 1: Josephine

Josephine is a Sustainable Transport Officer for the London Borough of Hyde Park.

The RT car club SuperCar has been operating in Hyde Park for approximately one year. Last week, Josephine received SuperCar's June 2020 CLADS data submission via email, which contains SuperCar's data for Hyde Park for the first quarter in 2020.

The raw data is shown in Figures 6.1–6.3[13], with each figure showing one of the data files described in Table 5.1 (Section 5).

- Figure 6.1 (user information): This data file provides the operator's name (SuperCar), user ID, residential location of users by LSOA, users' age and type of user (private or corporate);
- Figure 6.2 (parking location): This data file provides the operator's name, the local authority and the number of parking bays on a street (for both local authority concession and third-party);
- Figure 6.3 (trip information): This data file provides the basic information of the trips, including start/end location of the trips (represented by the street address), start/end time, trip length and vehicle plate number.

Josephine has been instructed by Hyde Park's councillors to provide a one-year overview of SuperCar's operations in the borough to help support a decision of whether to allow SuperCar to expand with additional on-street parking bays:

- who the users are;
- how users are using SuperCar (frequency, time of day/day of week and trip lengths);
- whether SuperCar's services have impacted demand for residential parking permits;
- whether SuperCar is providing equitable service to the London Borough of Hyde Park's deprived neighbourhoods;
- which SuperCar parking bays receive the highest vs lowest usage levels.

13 Despite the fiction, the data presented in Figures 6.1–6.3 was generated synthetically based on real-world data. This ensures that there is some realism in the overall distributions of the data while individual data entities are entirely fictional. This is indicated by the 'dummy data' watermark on these figures, as well as others throughout this report.

Figure 6.1: SuperCar user information dummy data

	A	B	C	D	E	F	G	H	I	J
1	LSOA	Operator_Name	User_ID	Age	User_Type					
2	E01004327	SuperCar	SU0115	36	Private User					
3	E01004327	SuperCar	SU4609	20	Private User					
4	E01004327	SuperCar	SU2359	36	Private User					
5	E01004327	SuperCar	SU0401	19	Private User					
6	E01004327	SuperCar	SU25[illegible]	31	Corporate User					
7	E01004327	SuperCar	SU2[illegible]39	25	Private User					
8	E01004327	SuperCar	SU0301	22	Private User					
9	E01004327	SuperCar	SU2105	43	Corporate User					
10	E01004327	SuperCar	SU2019	3[illegible]	Private User					
11	E01004327	SuperCar	SU3782	47	Private User					
12	E0100432[illegible]	SuperCar	SU3423	57	Private User					
13	E01004327	SuperCar	SU3960	41	Private User					
14	E01004328	SuperCar	SU4364	18	Private User					
15	E01004328	SuperCar	SU4203	22	Corporate User					
16	E01004328	SuperCar	SU4532	45	Private User					
17	E01004328	SuperCar	SU4685	20	Corporate User					

Source: Authors' own

Figure 6.2: SuperCar parking location dummy data

	A	B	C	D	E
1	Operator_Name	Local_Authority	Street_Address	Number of Local Authority Concession Parking Bays	Number of Third Party Concession Parking Bays
2	SuperCar	Hyde Park	VBU Street	0	0
3	SuperCar	Hyde Park	IIB Street	0	2
4	SuperCar	Hyde Park	HGV Street	4	1
5	SuperCar	Hyde Park	ZRP Street	2	0
6	SuperCar	Hyde Park	AIJ Street	1	0
7	SuperCar	Hyde Park	EOU Street	4	0
8	SuperCar	Hyde Park	SPA Street	2	3
9	SuperCar	Hyde Park	DPG Street	0	0
10	SuperCar	Hyde Park	[illegible]OL Street	1	0
11	SuperCar	Hyde Park	SP[illegible] Street	2	2
12	SuperCar	Hyde Park	FCQ Street	1	0
13	SuperCar	Hyde Park	TAW Street	[illegible]	0
14	SuperCar	Hyde Park	SXK Street	[illegible]	0
15	SuperCar	Hyde Park	HDC Street	1	0
16	SuperCar	Hyde Park	VGS Street	0	1
17	SuperCar	Hyde Park	BVZ Street	4	0
18	SuperCar	Hyde Park	LYJ Street	0	1
19	SuperCar	Hyde Park	FUC Street	0	0
20	SuperCar	Hyde Park	WZC Street	0	0

Source: Authors' own

Figure 6.3: SuperCar (round) trip information dummy data

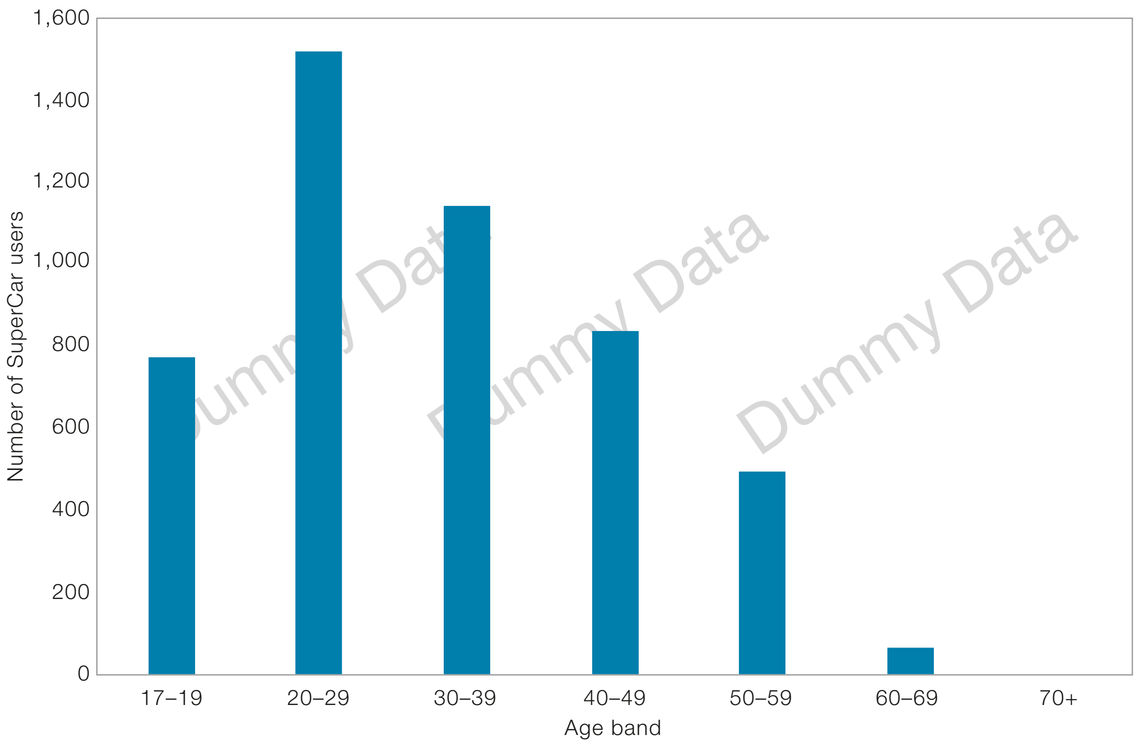
	A	B	C	D	E	F	G	H	I	J	K
1	Operator_Name	Trip_ID	User_ID	Licence_Plate_number	Trip_Start_time	Trip_End_time	Parking_bay_street_address	Trip_Length	Charge_Start	Charge_End	Charging _During_Trip
2	SuperCar	ST4905740	SU10000	YW55LEF	21/03/2020 16:51	21/03/2020 17:12	ZXG Street	13.47630617	Petrol Vehicle	Petrol Vehicle	N/A
3	SuperCar	ST4654751	SU10000	PC98IKH	18/01/2020 14:35	18/01/2020 15:12	ZJC Street	8.314673014	81%	73%	51%
4	SuperCar	ST2962169	SU10000	XY34GCJ	09/04/2020 11:55	09/04/2020 12:21	ZTJ Street	17.10710819	38%	29%	14%
5	SuperCar	ST1461535	SU10000	JX33BGY	27/01/2020 00:56	27/01/2020 01:17	KDB Street	9.921891971	Petrol Vehicle	Petrol Vehicle	N/A
6	SuperCar	ST1122471	SU10000	QN94MVW	31/12/2019 16:26	31/12/2019 17:17	YNF Street	5.453990968	Petrol Vehicle	Petrol Vehicle	N/A
7	SuperCar	ST4566814	SU10000	NW49DGY	21/02/2020 15:26	21/02/2020 16:35	EZP Street	2.196646312	18%	17%	42%
8	SuperCar	ST4442886	SU10001	ST54AIE	[illegible]6/12/2019 10:50	26/12/2019 11:45	UUK Street	13.23654191	Petrol Vehicle	Petrol Vehicle	N/A
9	SuperCar	ST7349076	SU10001	NU22RNJ	19/02/2020 22:43	19/02/2020 23:33	RUZ Street	4.981646218	Petrol Vehicle	Petrol Vehicle	N/A
10	SuperCar	ST6917490	SU10001	WM33WQX	06/03/2020 23:39	07/03/2020 00:22	IKQ Street	23.50382752	24%	[illegible]0%	18%
11	SuperCar	ST8654280	SU10001	DU71NLU	17/02/2020 18:32	17/02/2020 1[illegible]:27	JL[illegible] Street	2.45243999	Petrol Vehicle	Petrol Vehicle	N/A
12	SuperCar	ST1681929	SU10001	ER80PWM	07/01/2020 11:20	07/01/2020 12:[illegible]2	ZZ[illegible] Street	23.5002435	Petrol Vehicle	Petrol Vehicle	N/A
13	SuperCar	ST8383530	SU10001	AG82L[illegible]M	28/01/2020 14:57	28/01/2020 15:2[illegible]	[illegible]XK Street	18.51102324	9[illegible]	3%	20%
14	SuperCar	ST1145676	SU10001	CA[illegible]W[illegible]E	27/12/2019 12:56	27/12/2019 14:07	NMF Street	10.74118205	19%	17%	61%
15	SuperCar	ST6660632	SU1000[illegible]	C[illegible]3BI[illegible]	11/03/2020 19:53	[illegible]/03/2020 20:37	BAH Street	23.7183[illegible]5	46%	24%	62%
16	SuperCar	ST7793397	SU10002	MD46U[illegible]K	04/02/2020 2[illegible]:1[illegible]	04/02/2020 22:53	SPN Street	1.2992[illegible]776[illegible]	Petrol Vehicle	Petrol Vehicle	N/A
17	SuperCar	ST8418282	SU1[illegible]	IS54QRM	31/12/20[illegible] 11:[illegible]	[illegible]1/12/2019 11:52	KTG Street	[illegible].21[illegible]58[illegible]72	22%	12%	81%
18	SuperCar	ST8123579	S[illegible]10002	YH85WTZ	05/0[illegible]/2020 0[illegible]:11	05/02/2020 04:03	ETW Street	17.[illegible]6533739	46%	40%	67%
19	SuperCar	ST[illegible]27	SU10002	BU31SRI	1[illegible]/01/2020 06:58	10/01/2020 07:08	RPM Street	[illegible]6.50505758	92%	36%	20%
20	SuperCar	[illegible]T1537[illegible]	SU10002	GL31SMC	[illegible]5/0[illegible]/2020 21:56	05/02/2020 22:15	AGQ Street	8.125992031	74%	27%	93%
21	SuperCar	S[illegible]219[illegible]40	SU10002	LH95UTZ	[illegible]4/03/2020 20:10	14/03/2020 21:17	NZB Street	3.291385201	87%	68%	56%
22	SuperCar	ST3789206	SU10003	QX46GOX	26/12/2019 23:48	27/12/2019 00:20	THF Street	22.15286584	Petrol Vehicle	Petrol Vehicle	N/A
23	SuperCar	ST3128508	SU10003	GJ68LNU	27/03/2020 08:03	27/03/2020 08:34	OCH Street	1.490699594	25%	15%	77%
24	SuperCar	ST5332857	SU10003	JE11PKM	27/12/2019 02:13	27/12/2019 03:05	PTB Street	5.293016299	79%	49%	6%
25	SuperCar	ST4745686	SU10003	BB78TYI	23/01/2020 04:10	23/01/2020 04:58	XVP Street	6.928373505	79%	25%	95%
26	SuperCar	ST9126793	SU10003	WO83ZON	15/03/2020 08:38	15/03/2020 09:23	GHP Street	4.240027567	1%	1%	99%

Source: Authors' own

6.1.1 Who are the users?

The user information provided by SuperCar is limited. All information that Josephine can obtain from the data is the age distribution of users from the User Information file (Figure 6.4). The age distribution is skewed to the left (Figure 6.4), which suggests that SuperCar users are mainly young people in their twenties.

Figure 6.4: Age distribution of SuperCar users

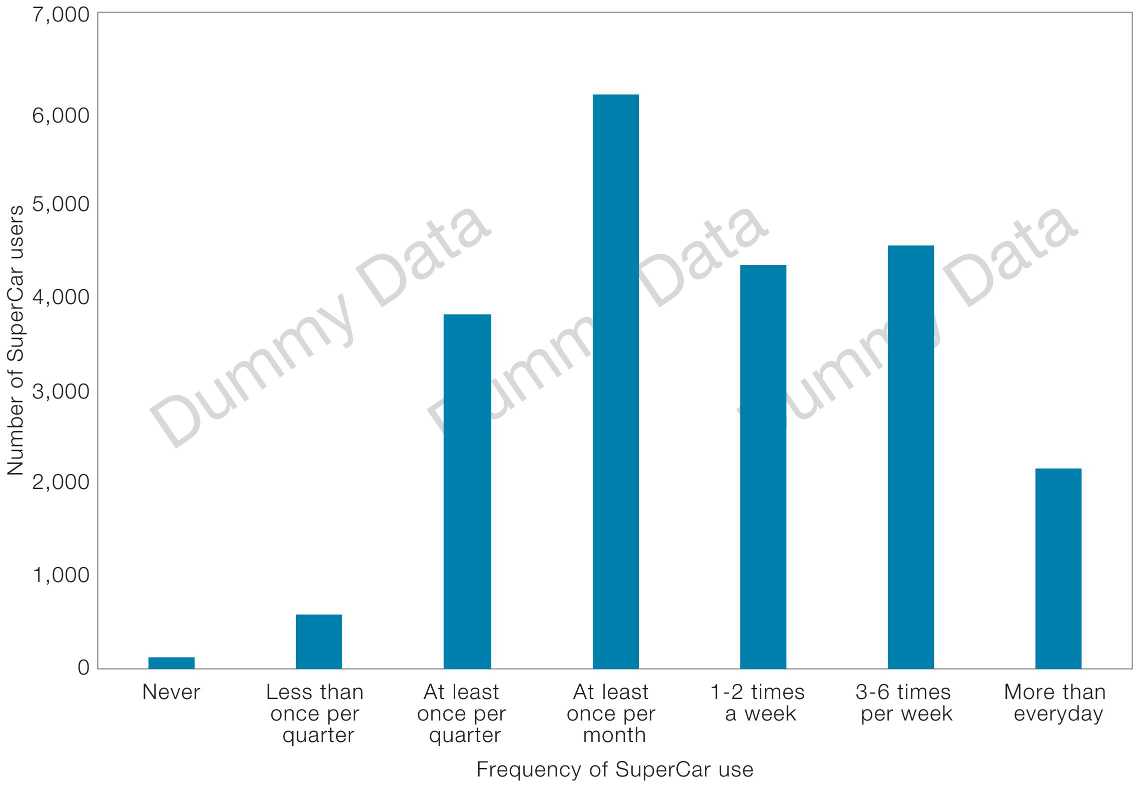


Source: Authors' own analysis

6.1.2 How are users using SuperCar (frequency, time of day/day of the week and trip lengths)?

Josephine obtained the distribution of SuperCar users by frequency of use from the Trip Information file. She aggregated the Trip Information file by user ID and plotted the number of SuperCar users by their usage frequency in Figure 6.5. In general, most SuperCar users use the service less than once a week. It can be seen that 0.5% of registered members have never used the service, thus are more accurately considered 'registered' rather than 'users' of SuperCar.

Figure 6.5: SuperCar user distribution by frequency of use

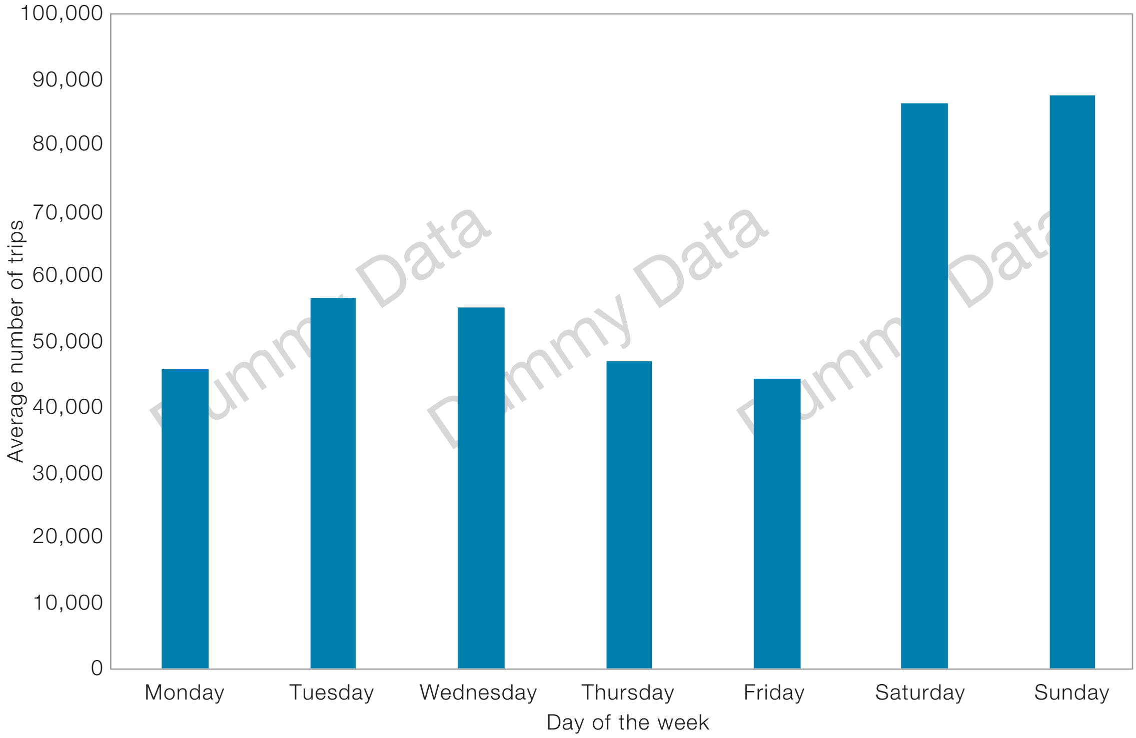


Source: Authors' own analysis

The trip frequency distributions by time of day and day of week are also obtained from the Trip Information file and are presented in Figures 6.6 and 6.7, respectively.

According to Figure 6.6, SuperCar users use the service mainly during the weekends.

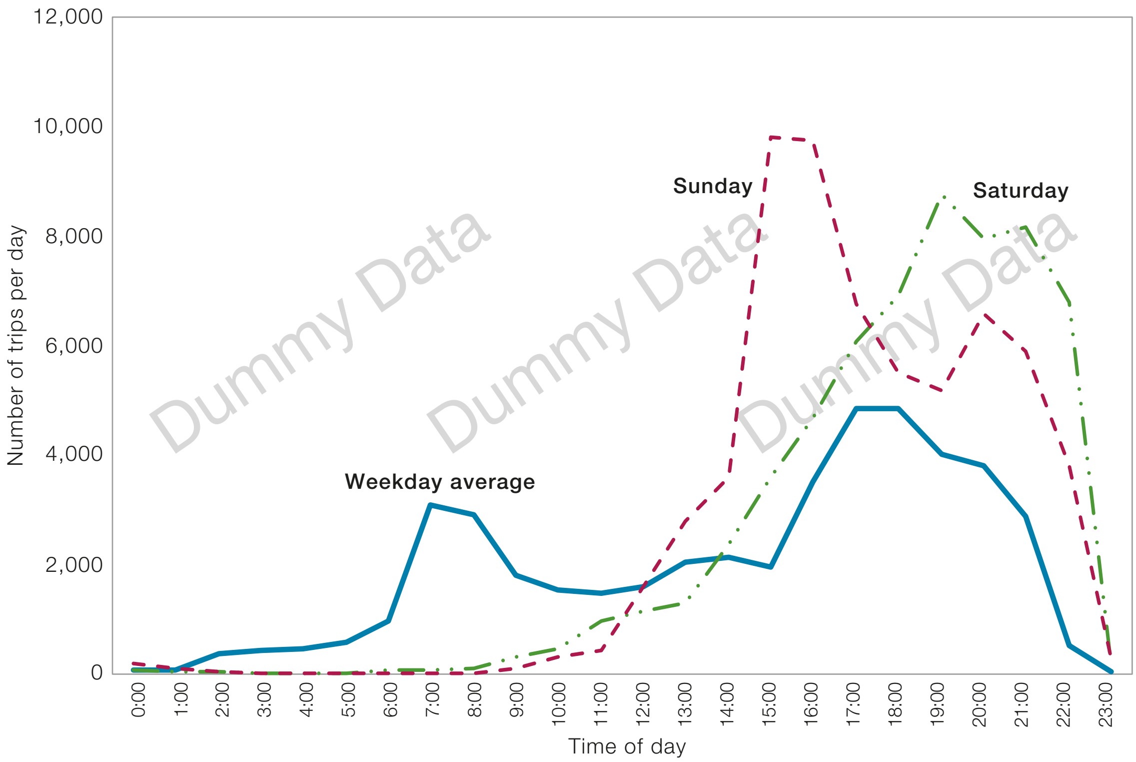
Figure 6.6: Number of SuperCar trips by day of the week



Source: Authors' own analysis

Figure 6.7 shows that the time-of-day patterns of SuperCar use during weekdays and weekends are very different. Josephine finds that there are two peaks during weekdays, with one in the morning and the other in the afternoon. For Saturday and Sunday, only one peak appears in the time-of-day curve, and it appears in the afternoon. The peak appears later in the day for Saturdays and earlier for Sundays. Figure 6.6 and 6.7 together suggest that SuperCar is used mainly for recreational purposes rather than commuting.

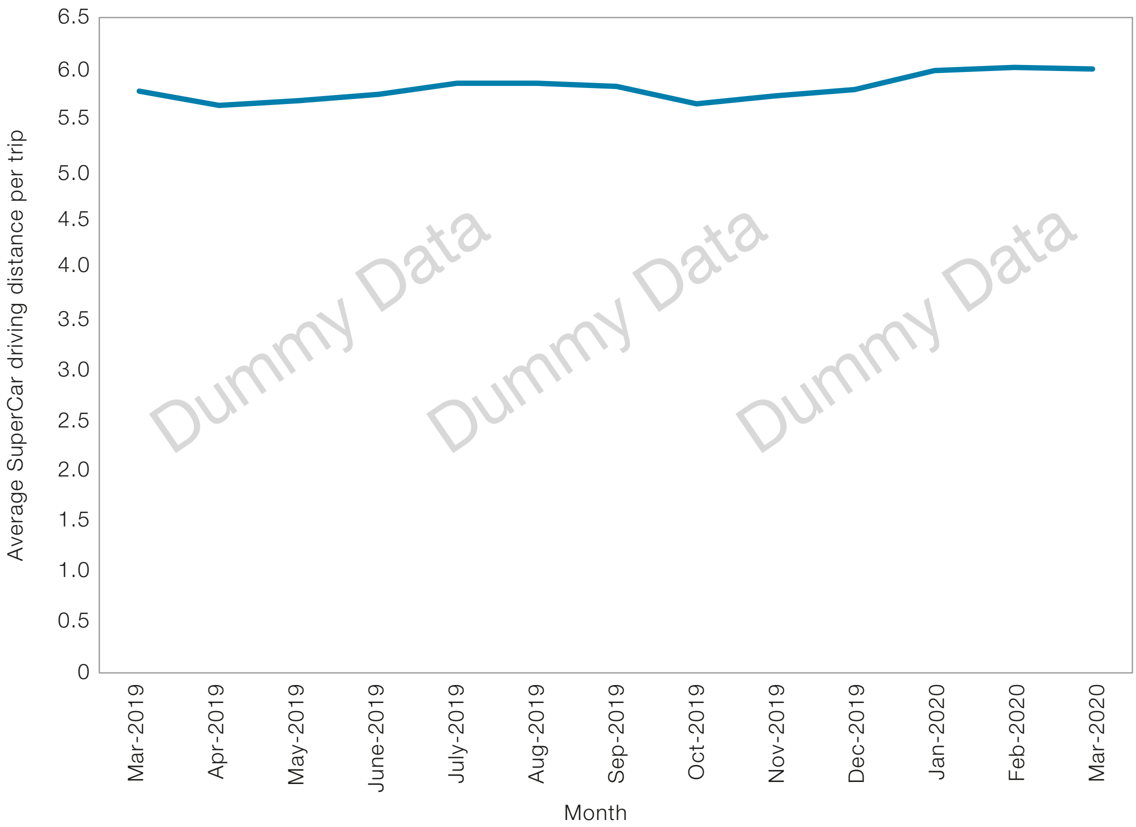
Figure 6.7: Number of SuperCar trips by time of day



Source: Authors' own analysis

Josephine plotted the average driving distance per trip of SuperCar trips from March 2019 to March 2020 in Figure 6.8. This information is reported by SuperCar in the summary statistics. Figure 6.8 shows that, the average trip length has remained generally stable at approximately six miles.

Figure 6.8: SuperCar trip length

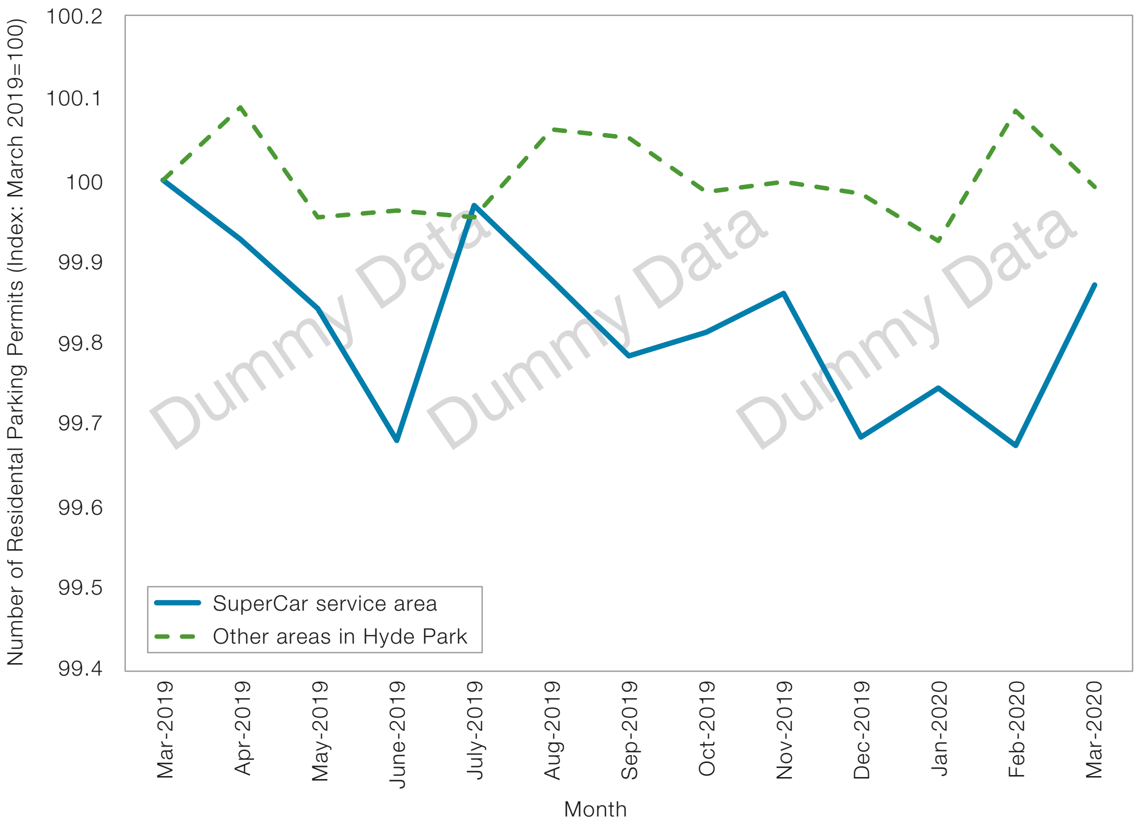


Source: Authors' own analysis

6.1.3 Have SuperCar's services impacted the demand for residential parking permits?

To work this out, Josephine needed to integrate the Parking Location file to Hyde Park's residential parking permits data. She used the number of residential parking permits in March 2019 as the reference and computed the change of residential parking numbers per LSOA from March 2019 to March 2020. She plotted this change as shown in Figure 6.9. Although not by much (approximately 0.4%), the trend of residential parking needs in the SuperCar service area is going downwards compared to other areas in Hyde Park. Hence, Josephine can conclude that SuperCar is potentially helpful in reducing residential parking needs in the borough.

Figure 6.9: Change of residential parking permits



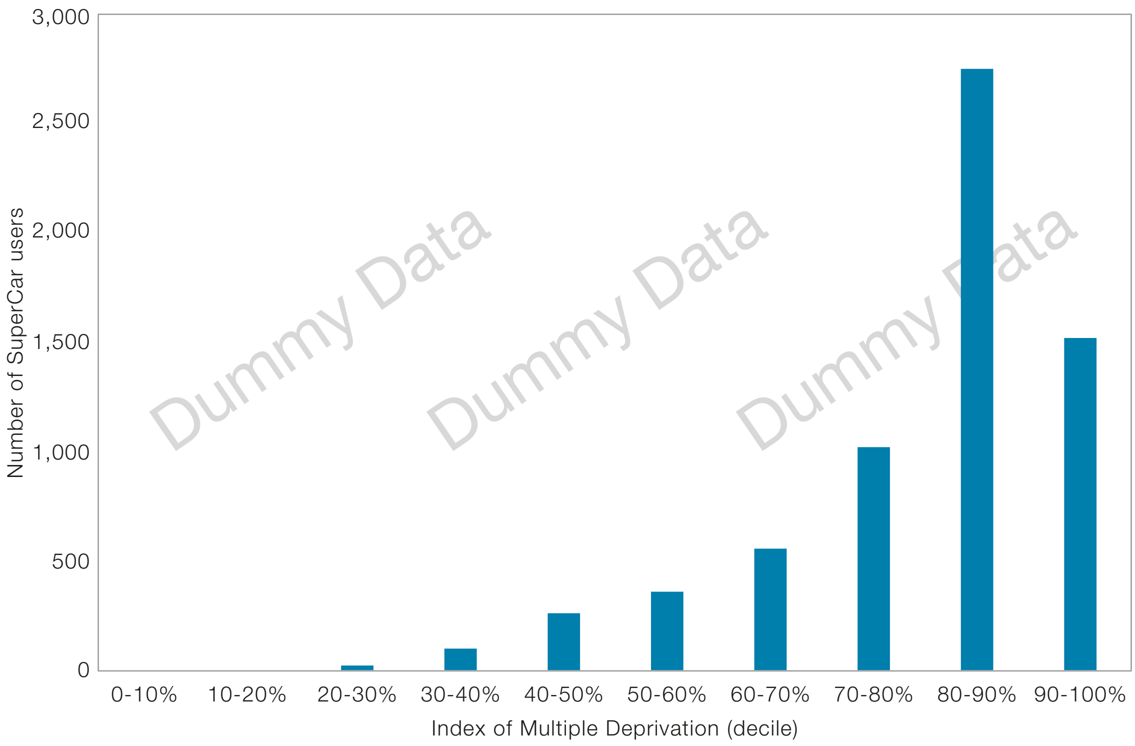
Source: Authors' own analysis

6.1.4 Is SuperCar providing equitable service to Hyde Park's deprived neighbourhoods?

Josephine appended the User Information file with the IMD information (Ministry of Housing, Communities and Local Government, 2019) and plotted the number of SuperCar user distribution by IMD (Figure 6.10). The IMD is structured so that higher IMD values are associated with higher-income neighbourhoods.

Figure 6.10 shows that the distribution of number of SuperCar users is skewed to the right, so SuperCar users mainly live in richer neighbourhoods with higher IMD. Hyde Park should continue working on the equitable access of SuperCar service in more deprived neighbourhoods.

Figure 6.10: Index of Multiple Deprivation (IMD) of SuperCar users' LSOA of residence

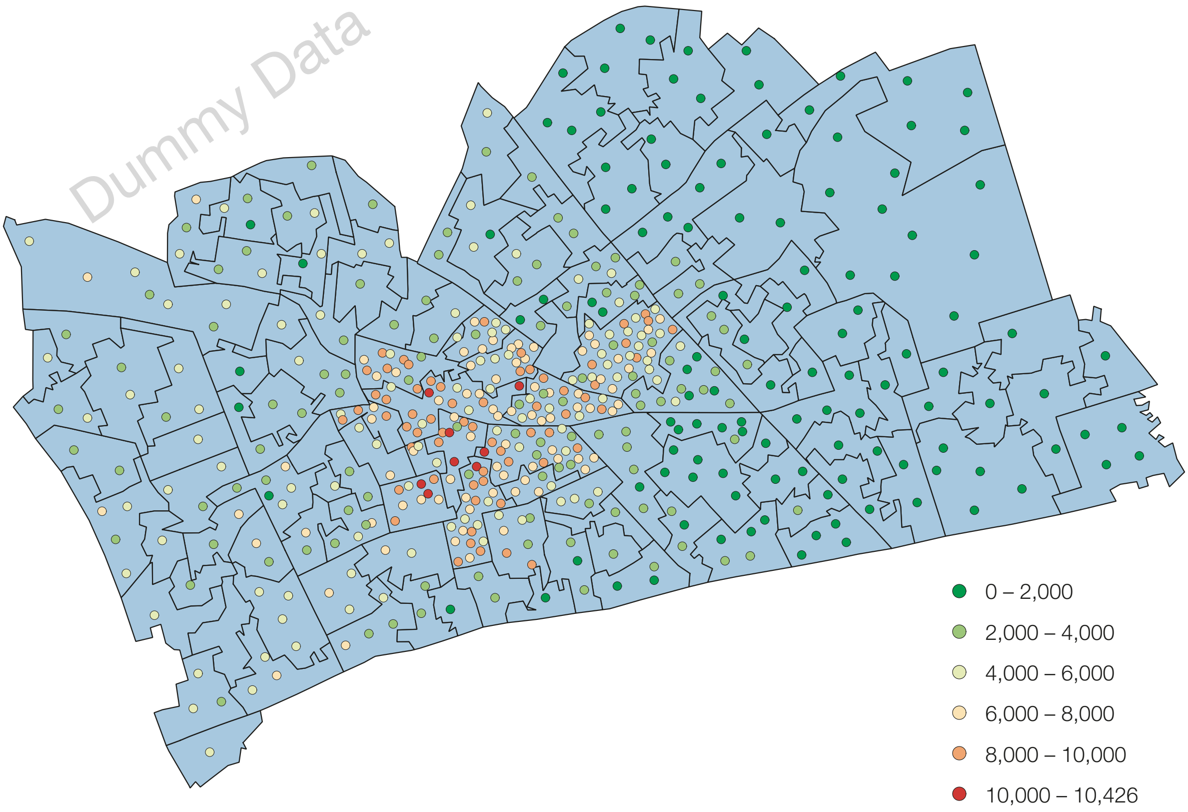


Source: Authors' own analysis

6.1.5 Which SuperCar parking bays receive the highest vs lowest usage levels?

Josephine aggregated the Trip Information file by bay ID and obtained the average number of trips per month for each bay. For simplicity, each street segment is represented as a single point at its centroid; Josephine plotted the average number of trips of each street segment (Figure 6.11). The figure shows a clear pattern that bays in central Hyde Park were used more frequently. It is unclear whether the low usage frequency close to the boundary is caused by poor access to the service or residents' attitude towards the car club. Josephine and colleagues need to have a better understanding of it and then decide whether to increase SuperCar bays in these areas to promote the accessibility of the SuperCar service or decrease the number of SuperCar bays.

Figure 6.11: Average SuperCar bay usage frequency per month



Source: Authors' own analysis

Will a local authority be able to access CLADS data from other local authorities?

The present document is agnostic as to the question of which entity will have control over CLADS data. This issue will be explored by stakeholders and decided in due course as the CLADS standard moves towards implementation, as discussed further in Section 7.

If data from different local authorities is accessible to one another, then Josephine would be able to benchmark SuperCar's car club operations in Hyde Park against its performance in other boroughs.

Perhaps she may find that SuperCar does relatively well in Hyde Park at serving low-income communities compared to peer London boroughs and that SuperCar's number of off-street bays in Hyde Park has been growing more quickly than in neighbouring boroughs. When discussing this with SuperCar, she learns that the operator has done similar analysis and would like to request additional on-street bays in Hyde Park. Given that she can credibly verify this phenomenon, she is confident in drafting a memorandum to her councillors in support of such action.

6.1.6 Summary

The case study of 'Josephine' demonstrates how CLADS data can be applied to develop findings such as these fictional results for SuperCar in the London Borough of Hyde Park:

- SuperCar is mainly used by young adults living in richer neighbourhoods.
- SuperCar is mainly used for recreational purposes.
- SuperCar may contribute to the reduction in residential parking needs (implying perhaps a reduction in private car ownership).
- SuperCar provides relatively poor service access to low-income neighbourhoods.
- SuperCar bays are used less frequently in outer Hyde Park, which could be caused by the poor service access.

6.2 Fictional scenario 2: Clyde

Clyde is the Director of Parking Management for the London Borough of Kew Gardens. Like Josephine, he received data from the FFCS operator, Drive-n-Go, in the last week. Clyde is instructed by councillors to benchmark Drive-n-Go's and SuperCar's operations in the two London boroughs. Councillors are perplexed that Drive-n-Go's user base has not grown as quickly as they had expected.

The raw data that Clyde received from Drive-n-Go are shown in Figures 6.12–6.14. Figures 6.12 and 6.14 are User Information and Trip Information files, which are similar to Figures 6.1 and 6.3 in Section 6.1, respectively. Figure 6.13 shows the number of FFCS vehicles in Kew Gardens, which updates four times in a day.

Figure 6.12: Drive-n-Go user information dummy data

	A	B	C	D	E	F	G	H	I	J
1	Operator_Name	User_ID	LSOA	Age	User_Type					
2	Drive-n-Go	DU0115	E01004327	31	private user					
3	Drive-n-Go	DU4609	E01004327	26	private user					
4	Drive-n-Go	DU2359	E01004327	36	private user					
5	Drive-n-Go	DU0401	E01004327	19	private user					
6	Drive-n-Go	DU2573	E01004327	37	private user					
7	Drive-n-Go	DU2939	E01004327	23	private user					
8	Drive-n-Go	DU0301	E01004327	28	private user					
9	Drive-n-Go	DU2105	E01004327	46	private user					
10	Drive-n-Go	DU2019	E01004327	37	private user					
11	Drive-n-Go	DU3782	E01004327	46	private user					
12	Drive-n-Go	DU3423	E01004327	55	private user					
13	Drive-n-Go	DU3960	E01004327	44	private user					
14	Drive-n-Go	DU4364	E01004328	18	private user					
15	Drive-n-Go	DU4203	E01004328	22	private user					
16	Drive-n-Go	DU4532	E01004328	45	private user					

Source: Authors' own

Figure 6.13: Drive-n-Go vehicle distribution dummy data

	A	B	C	D	E	F	G	H
1	Operator_Name	Local_Authority	Number_of_FFCS_Vehicles	Update_Date	Update_Time			
2	Drive-n-Go	Kew Gardens	2313	1/1/2020	9am			
3	Drive-n-Go	Kew Gardens	2719	1/1/2020	12pm			
4	Drive-n-Go	Kew Gardens	1923	1/1/2020	15pm			
5	Drive-n-Go	Kew Gardens	1903	1/1/2020	12am			
6	Drive-n-Go	Kew Gardens	1044	2/1/2020	9am			
7	Drive-n-Go	Kew Gardens	2419	2/1/2020	12pm			
8	Drive-n-Go	Kew Gardens	1802	2/1/2020	15pm			
9	Drive-n-Go	Kew Gardens	1146	2/1/2020	12am			
10	Drive-n-Go	Kew Gardens	2751	3/1/2020	9am			
11	Drive-n-Go	Kew Gardens	1213	3/1/2020	12pm			
12	Drive-n-Go	Kew Gardens	1315	3/1/2020	15pm			
13	Drive-n-Go	Kew Gardens	1522	3/1/2020	12am			
14	Drive-n-Go	Kew Gardens	1841	4/1/2020	9am			
15	Drive-n-Go	Kew Gardens	1057	4/1/2020	12pm			
16	Drive-n-Go	Kew Gardens	1421	4/1/2020	15pm			
17	Drive-n-Go	Kew Gardens	1952	4/1/2020	12am			

Source: Authors' own

Figure 6.14: Drive-n-Go (FFCS) trip information dummy data

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Operator_Name	Trip_ID	User_ID	Licence_Plate_Number	Trip_Start_Time	Trip_End_Time	Trip_Start_Latitude	Trip_Start_Longitude	Trip_End_Latitude	Trip_End_Longitude	Trip_Length	Charge_Start	Charge_End
2	Drive-n-Go	DT8558393	DU2929	GR32UHL	22/02/2020 21:52	22/02/2020 22:10	51.517133	-0.134244	51.541891	-0.133231	1.12	69%	22%
3	Drive-n-Go	DT9437553	DU1470	YY29EMD	30/03/2020 01:00	30/03/2020 01:42	51.518808	-0.191859	51.510557	-0.118919	1.15	Petrol Vehicle	Petrol Vehicle
4	Drive-n-Go	DT5480696	DU1476	FP39NIB	21/02/2020 18:33	21/02/2020 18:49	51.515812	-0.12134	51.512513	-0.191777	1.31	25%	18%
5	Drive-n-Go	DT7264716	DU4161	ZE94ZEH	08/01/2020 01:11	08/01/2020 01:44	51.521242	-0.115106	51.508415	-0.142497	0.8	16%	11%
6	Drive-n-Go	DT4528841	DU2968	PV13ARH	30/01/2020 14:39	30/01/2020 15:15	51.515768	-0.111354	51.51542	-0.112031	1.5	82%	52%
7	Drive-n-Go	DT1903952	DU0794	EC37HFS	26/03/2020 11:27	26/03/2020 11:29	51.499166	-0.158159	51.488258	-0.168466	1.78	Petrol Vehicle	Petrol Vehicle
8	Drive-n-Go	DT7882022	DU1087	KK92EHM	18/01/2020 05:48	18/01/2020 06:01	51.530754	-0.206769	51.515009	-0.15801	1.68	41%	13%
9	Drive-n-Go	DT3102405	DU0991	TX68QOQ	18/02/2020 12:03	18/02/2020 12:13	51.514572	-0.201179	51.517133	-0.134244	1.5	Petrol Vehicle	Petrol Vehicle
10	Drive-n-Go	DT9064441	DU3160	JZ19PYU	08/03/2020 04:24	08/03/2020 04:36	51.507909	-0.144636	51.514224	-0.148141	2.01	40%	26%
11	Drive-n-Go	DT6215150	DU4586	FP39NIB	23/03/2020 22:58	23/03/2020 23:26	51.496429	-0.137437	51.514044	-0.155541	0.32222675	Petrol Vehicle	Petrol Vehicle
12	Drive-n-Go	DT4857374	DU3931	YY29EMD	12/03/2020 10:17	12/03/2020 10:31	51.512501	-0.119433	51.513477	-0.139019	1.45	Petrol Vehicle	Petrol Vehicle
13	Drive-n-Go	DT4522183	DU3455	IX75ECZ	27/01/2020 22:14	27/01/2020 22:27	51.521485	-0.164999	51.509543	-0.138214	1.98	Petrol Vehicle	Petrol Vehicle
14	Drive-n-Go	DT8071520	DU2166	OX24OQF	[illegible]	[illegible]	51.535673	[illegible]	51.517133	-0.134244	[illegible]	[illegible]	Petrol Vehicle
15	Drive-n-Go	DT5030443	DU0619	KK92EHM	[illegible]	[illegible]	51.520453	[illegible]	51.502246	-0.161882	[illegible]	88%	33%
16	Drive-n-Go	DT4755407	DU4791	IA43AXH	[illegible]	06/02/2020 02:48	51.530784	[illegible]	51.486882	-0.188729	[illegible]	54%	23%
17	Drive-n-Go	DT5820498	DU2286	VF65LAC	[illegible]	20/02/2020 10:31	[illegible]	[illegible]	51.512417	[illegible]	[illegible]	Petrol Vehicle	Petrol Vehicle
18	Drive-n-Go	DT1391705	DU0668	FP39NIB	[illegible]	24/01/2020 14:42	51.511318	-0.136701	51.513799	-0.210548	[illegible]	Petrol Vehicle	Petrol Vehicle
19	Drive-n-Go	DT4420407	DU0969	JM68IAK	[illegible]	30/03/2020 18:27	[illegible]	-0.210104	51.509255	[illegible]	2.22	92%	61%
20	Drive-n-Go	DT6989643	DU4358	LF51GUL	13/03/2020 05:15	13/03/2020 05:57	[illegible]	-0.135461	51.512811	[illegible]	2.34	Petrol Vehicle	Petrol Vehicle
21	Drive-n-Go	DT8734093	DU4408	[illegible]	10/01/2020 07:38	10/01/2020 07:58	[illegible]	-0.134244	51.50663	[illegible]	0.627416958	18%	13%
22	Drive-n-Go	DT9484761	DU4078	[illegible]	04/02/2020 09:17	04/02/2020 09:30	[illegible]	-0.123493	51.516327	[illegible]	0.633615787	17%	14%
23	Drive-n-Go	DT3873610	DU1157	[illegible]	15/02/2020 17:26	[illegible]	51.519573	-0.175022	[illegible]	-0.150655	0.638256466	31%	12%
24	Drive-n-Go	DT5464901	[illegible]	[illegible]	06/03/2020 18:36	[illegible]	51.524271	-0.14374	[illegible]	-0.108562	0.640547006	Petrol Vehicle	Petrol Vehicle
25	Drive-n-Go	DT9762414	[illegible]	TX23GMI	22/03/2020 18:14	[illegible]	51.484683	-0.170438	[illegible]	-0.178177	0.678391531	39%	13%
26	Drive-n-Go	[illegible]	[illegible]	LF51GUL	[illegible]	[illegible]	51.512794	[illegible]	[illegible]	-0.112042	0.679673686	12%	11%
27	Drive-n-Go	[illegible]	[illegible]	DK18JRB	[illegible]	[illegible]	51.516402	[illegible]	[illegible]	-0.159843	0.682416471	11%	9%
28	Drive-n-Go	[illegible]	DU0571	KK92EHM	[illegible]	[illegible]	51.517133	-0.134244	51.511553	-0.126632	0.695296962	Petrol Vehicle	Petrol Vehicle
29	Drive-n-Go	DT3371432	DU2770	HJ99JTC	07/02/2020 06:05	07/02/2020 06:32	51.515534	-0.111883	51.517133	-0.134244	0.705623496	Petrol Vehicle	Petrol Vehicle
30	Drive-n-Go	DT5692489	DU1433	ZH37YTU	04/01/2020 12:42	04/01/2020 12:55	51.512954	-0.126545	51.488258	-0.168466	0.735364004	Petrol Vehicle	Petrol Vehicle
31	Drive-n-Go	DT6974338	DU2585	KK92EHM	07/03/2020 14:51	07/03/2020 14:54	51.529077	-0.125379	51.51347	-0.21732	0.745356807	46%	34%
32	Drive-n-Go	DT7557726	DU0693	AT16MVZ	10/01/2020 13:51	10/01/2020 14:21	51.516207	-0.146749	51.521802	-0.116366	0.753845774	Petrol Vehicle	Petrol Vehicle
33	Drive-n-Go	DT4638414	DU3241	UU56LPB	10/01/2020 08:22	10/01/2020 08:35	51.497992	-0.17453	51.522037	-0.150332	0.760059656	Petrol Vehicle	Petrol Vehicle
34	Drive-n-Go	DT1966979	DU0396	PE30HMY	19/03/2020 06:17	19/03/2020 06:56	51.510465	-0.148052	51.500442	-0.164952	0.799304684	21%	12%
35	Drive-n-Go	DT3391376	DU1411	EC37HFS	23/01/2020 01:01	23/01/2020 01:11	51.510066	-0.14792	51.493034	-0.174901	0.810598234	26%	19%
36	Drive-n-Go	DT3061810	DU4439	SZ61KLO	21/03/2020 04:22	21/03/2020 04:43	51.507201	-0.137387	51.490967	-0.157697	0.810688937	Petrol Vehicle	Petrol Vehicle
37	Drive-n-Go	DT1829752	DU3238	SH34DAC	11/02/2020 21:22	11/02/2020 21:26	51.511496	-0.191029	51.521161	-0.132522	0.817577414	44%	43%
38	Drive-n-Go	DT6107351	DU1418	JZ19PYU	01/01/2020 12:24	01/01/2020 12:26	51.518039	-0.149413	51.511041	-0.156182	0.841132737	88%	81%
39	Drive-n-Go	DT4357854	DU0092	QV10GZT	22/01/2020 15:42	22/01/2020 16:10	51.500495	-0.276985	51.518621	-0.15269	0.856462789	64%	27%
40	Drive-n-Go	DT1243150	DU2327	SU51GXW	22/03/2020 10:36	22/03/2020 10:51	51.509161	-0.144181	51.513316	-0.192595	0.856581853	Petrol Vehicle	Petrol Vehicle

Source: Authors' own

Clyde and Josephine decide to summarise their CLADS data to quantify, for their respective boroughs:

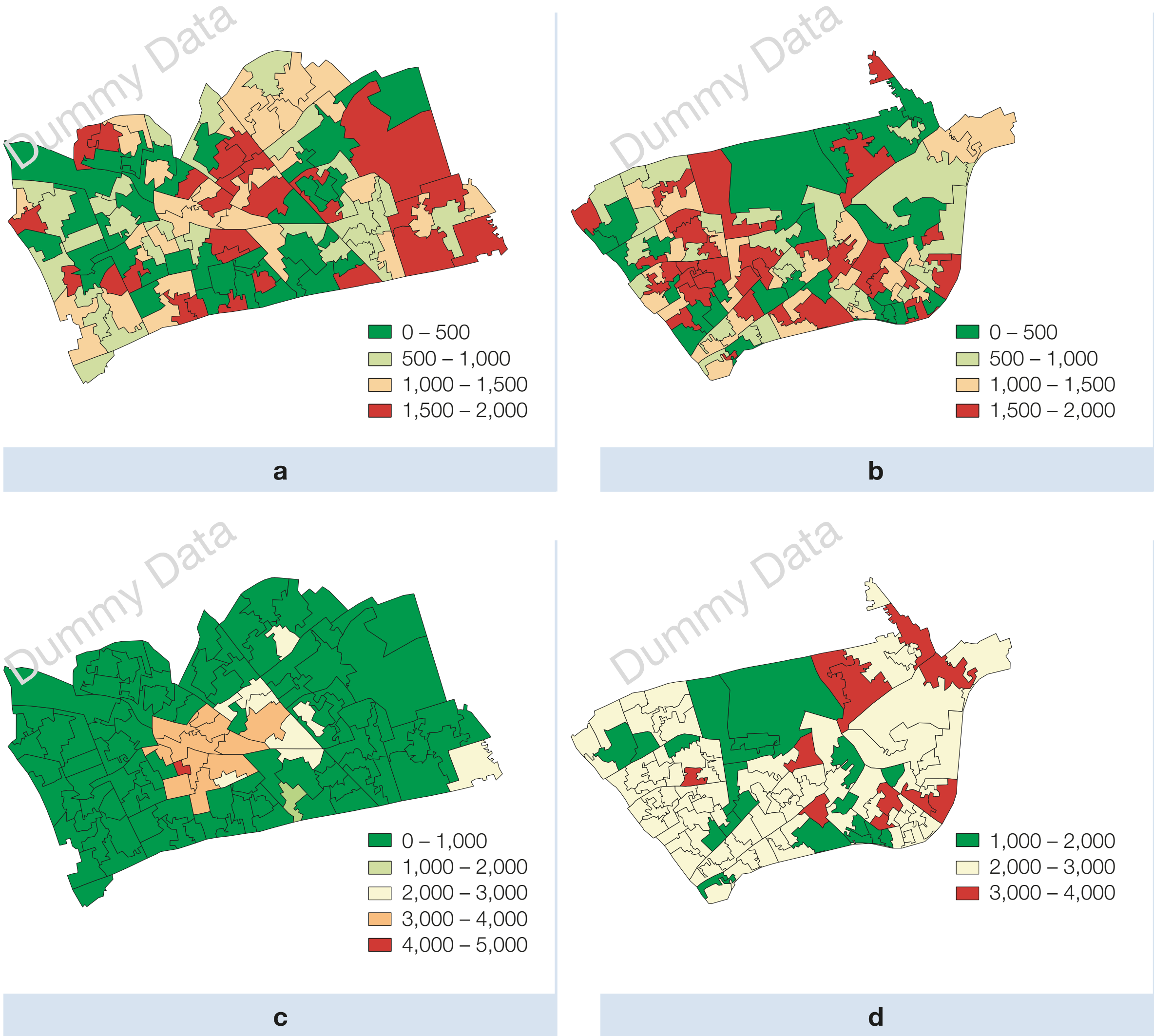
- how the locations served by the operators have changed over time;
- how the day-of-week distributions have changed over time;
- the roll-out of EVs in the car club fleets.

To make sure that the differences in the results are caused by the data only, Josephine shared her data analysis code with Clyde.

6.2.1 How have the locations served by the operators changed over time?

Clyde and Josephine computed the average number of car club trips of each LSOA and plotted the numbers, which are shown in Figure 6.15. They find that the use of both SuperCar and Drive-n-Go was equally distributed in March 2019 (**a**,**b**), but the use of SuperCar was concentrated to central Hyde Park one year later, whereas the use of Drive-n-Go is still evenly distributed across Kew Gardens (**c**,**d**).

Figure 6.15: Average trip frequency per month by LSOA. a, Hyde Park, March 2019. b, Kew Gardens, March 2019. c, Hyde Park, March 2020. d Kew Gardens, March 2020

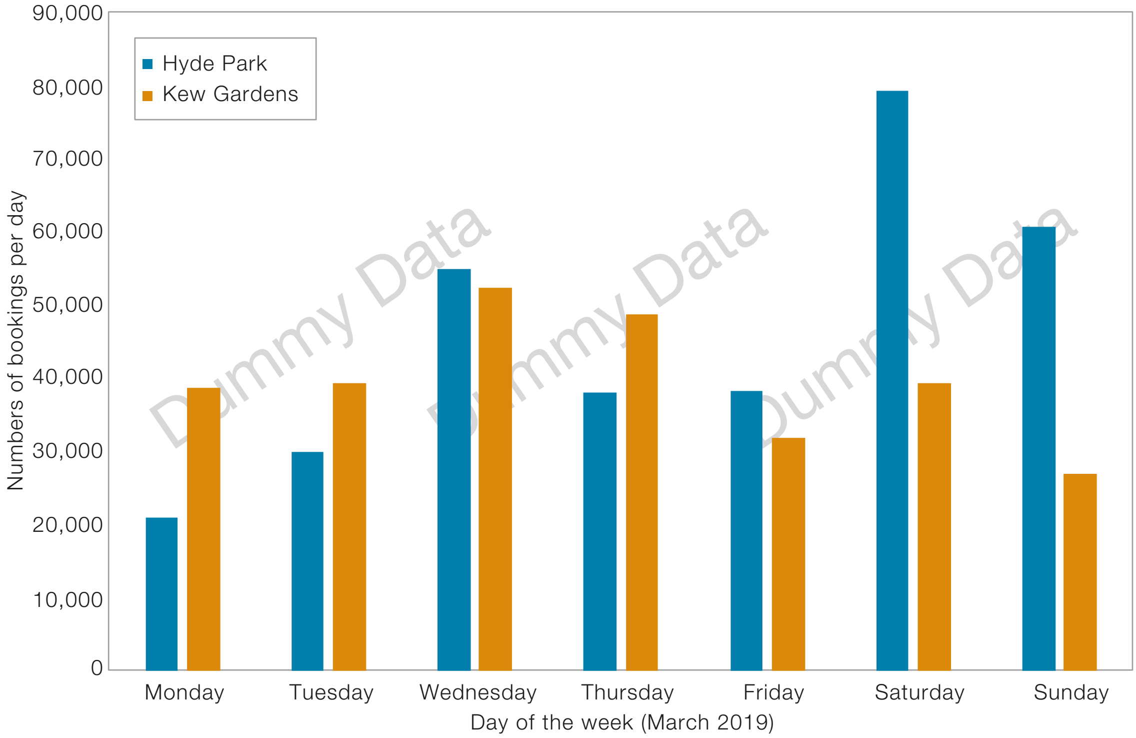


Source: Authors' own analysis

6.2.2 How have the day-of-week distributions changed over time?

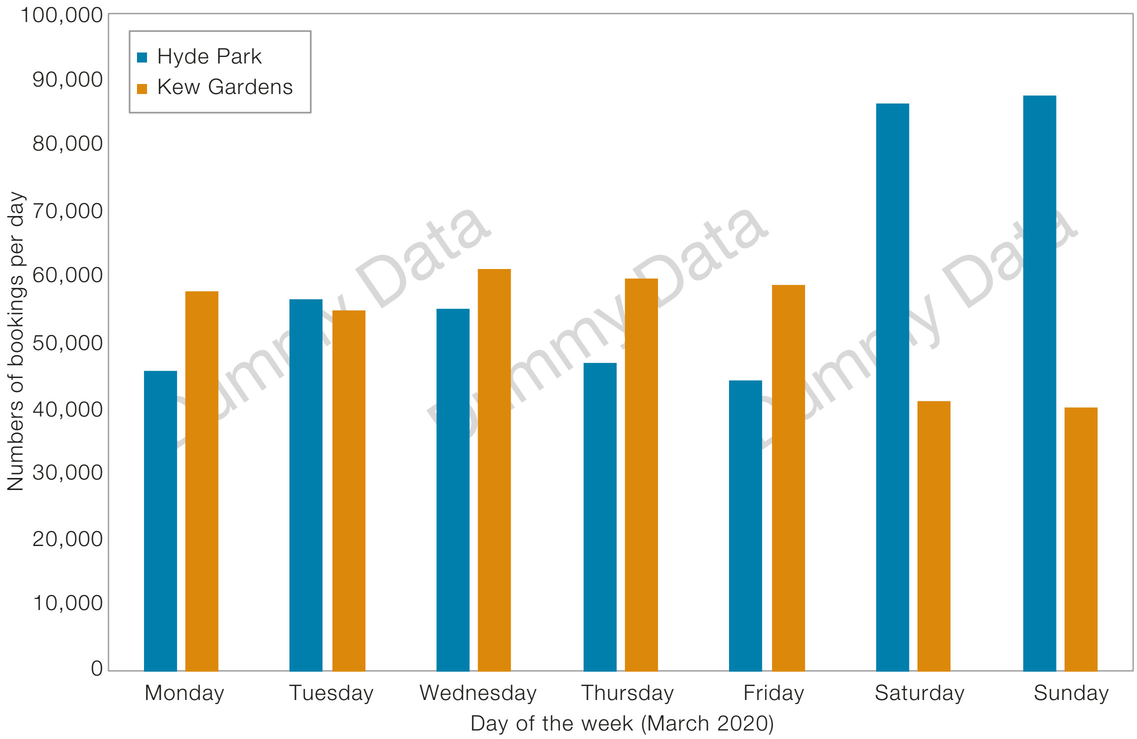
Clyde compared the day-of-week distribution of Kew Gardens against Hyde Park's (shown in Figure 6.16). He found that unlike SuperCar in Hyde Park, Drive-n-Go is used more frequently during the weekdays and this pattern is consistent from March 2019 to March 2020 (Figure 6.17). It could be that Drive-n-Go vehicles are used more often in commuting trips.

Figure 6.16: Day-of-week distribution of car club trips, March 2019



Source: Authors' own analysis

Figure 6.17: Day-of-week distribution of car club trips, March 2020



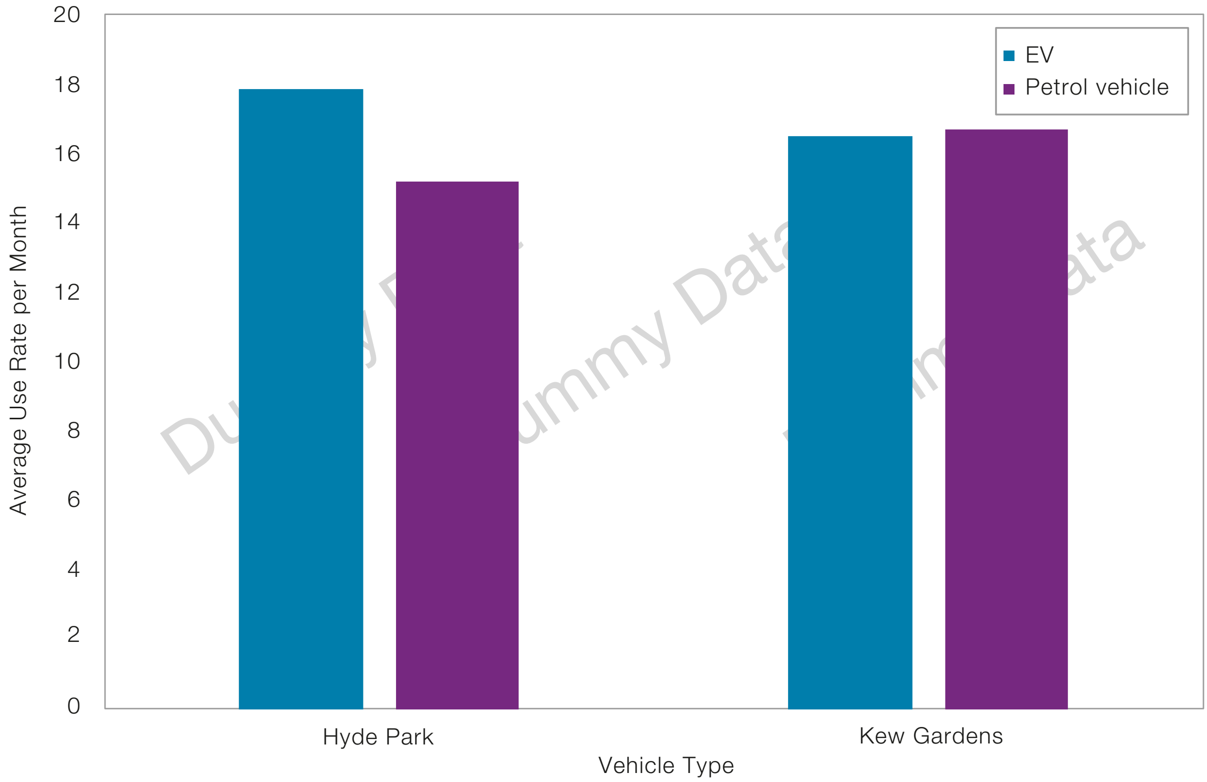
Source: Authors' own analysis

6.2.3 Roll-out of EVs in the car club fleets

Clyde and Josephine aggregated the trip information data by vehicle type and calculated the average frequency of use of electric and petrol vehicles. Both SuperCar and Drive-n-Go have a 50% of EVs in their fleets.

Clyde finds that EVs are used more frequently in Hyde Park and the frequency of use of electric and petrol vehicles are very close in Kew Gardens (see Figure 6.18). Kew Gardens may need to think of ways of promoting the use of EVs this year.

Figure 6.18: Frequency of electric vs petrol vehicle usage



Source: Authors' own analysis

6.2.4 Summary

The case study of 'Clyde' demonstrates how CLADS data can be applied to the benchmark findings of one local authority with a different local authority. Comparing the fictional results of Drive-n-Go in the London Borough of Kew Gardens with the fictional results for SuperCar in the London Borough of Hyde Park, we find that:

- Drive-n-Go is used mainly during weekdays, probably in commuting trips.
- The frequency of use is evenly distributed across LSOAs in the London Borough of Kew Gardens, which suggests that equity access to car club services is better in the London Borough of Kew Gardens compared to the London Borough of Hyde Park.
- The frequency of use of EVs should be further promoted in the London Borough of Kew Gardens.

6.3 Fictional scenario 3: Ahmed

Ahmed is a Data Management Associate for the London Borough of Kew Gardens. Councillors want to know whether public transport and active transport were competitive with regards to Drive-n-Go journeys in terms of travel times. If **Yes**: the implication is that Drive-n-Go journeys could have been made via public transport/active travel. If **No**: the case that Drive-n-Go complements public transport/active travel is strengthened.

Ahmed processes the CLADS journey-level data through the Google Maps API to obtain the following alternative journey times for Drive-n-Go journeys:

- How many minutes would each journey have taken by public transport?
- How many minutes would each journey have taken by walking?
- How many minutes would each journey have taken by cycling?

To answer the questions, Ahmed calculated the average travel time of Drive-n-Go trips from the central London Borough of Kew Gardens to the central London Borough of Hyde Park from the trip information data and obtained the average travel time by public transport, walking and cycling. The results are shown in Table 6.1.

Table 6.1: Summary of car club data sharing experiences in the London Borough of Kew Gardens

Mode of transport	Average duration of journey itinerary
Car club (Drive-n-Go)	28.3 min (calculated from observed CLADS data).
Public transport	106 min (estimated from processing CLADS origin/destination/day of week/ time of day through the Google Maps API).
Walking	234 min (also estimated via the Google Maps API).
Cycling	47 min (also estimated via the Google Maps API).

Source: Authors' own analysis

Ahmed concludes that, for Drive-n-Go journeys in the London Borough of Kew Gardens, public transport and walking are uncompetitive; however, cycling is more competitive compared to the car club service in terms of journey times.

7. Future considerations for the CLADS data sharing framework

The CLADS data standard is intended to be flexible to adapt as needs emerge in the future. As presented in this report the CLADS is designed in response to the analyses needs of the local authorities.

This section highlights a number of questions to be addressed as part of planning the roll-out of CLADS and the directions for refining CLADS in the future.

7.1 Who owns the data?

So far we have not discussed the ownership of the data. We assume car club operators would share with a specific local authority data that is directly relevant to this local authority. The local authority can perform any analyses based on the data, but they cannot share the raw data with other local authorities without the permission of the car club operator.

We discuss the benefit of making the data centrally owned (and readily accessible) in the textbox of Section 6.1.5. In summary, this will help the local authorities to easily benchmark their results with other local authorities and learn from the experiences of other local authorities.

Despite the benefits, there are potential risks to business and user privacy of opening up car club data in this manner. Additionally, it is important to establish ground rules to maximise the benefits while addressing the risks. Who owns the data, how local authorities access the data and whether they have the power to share their data with other local authorities are important questions to be addressed.

7.2 Potential value of the data to analysts outside local authorities

Section 2.7 reveals that Communauto has collaborated with academic researchers for over a decade. New York City's one-year data sharing project (Section 3.2) is also collected in collaboration with University of California, Berkeley. Compared to analysts working for local authorities and car club operators, academic researchers can have a very different angle on the potential analyses that can be generated from the data. They may also use their professional skills in simulation, optimisation, machine learning, etc. to help the operators develop new algorithms or decision support tools, so that the car club service can better balance the needs of private enterprise against the needs of the transport system.

In Section 6, we assumed that local authorities do not have the right to share data with third parties, so we did not include these kind of examples. However, opening the data to analysts working at third-party institutions could bring benefits to both local authorities and car club operators. Whether local authorities can share the CLADS data with third parties is unclear at this time and this point merits further discussion.

7.3 Who maintains ownership of the data standard? How does this relate to a data sharing platform or repository?

A data standard, such as the CLADS, requires regular maintenance and revision to remain fit for purpose (see the discussion in Section 7.5 for examples). This is possible only if there is clarity as to who will maintain ownership of the data standard. By default, this will remain with the local authorities; however, split ownership can lead to the data standard evolving in different directions, which would then defeat the purpose of a common data standard. Therefore, it is necessary to put in place an entity that will represent the interests of all stakeholders in maintaining the CLADS.

A potentially independent, although related consideration is the development of a data repository or data sharing platform, which will also need regular maintenance. When both car club operators and local authorities have agreed on the contents of the data sharing framework, there is the question of how the large volumes of data will be shared, stored and queried. Where to save the data, who will maintain the data storage facilities and what kind of an interface needs to be in place to query the data, are all essential questions to be answered.

Moreover, the interface for data queries is just the tip of the iceberg. It may be useful to develop a suite of common analytical tools and services to explore the CLADS data and unlock its potential, both from the perspective of the local authorities and that of other public agencies. Such an analysis suite will also need regular support.

Third-party institutions, like universities and national laboratories, are generally recommended in the literature (D'Agostino et al., 2019) as potential custodians of data repositories. There are good examples of third-party data repositories in other countries: The Transportation Secure Data Center (TSDC), which is maintained by the National Renewable Energy Laboratory (NREL) through a partnership between the U.S. Department of Transportation and the U.S. Department of Energy. The TSDC aggregates data from both household travel surveys and data collected from GPS units and coverts the data into an anonymised, consistent format. Data analysts may apply for data access through NREL for specific purposes.

Within the UK specifically, the DfT, local government associations and local government bodies such as London councils, TfL, TfGM and/or TfWM, could collaborate with universities or other research agencies, and third-party stakeholders such as CoMoUK, to create a consortium to design, develop and maintain a data sharing platform(s). The data sharing platform(s) could manage the data (including data upload procedures), receive data access applications and grant different levels of data access to different types of data analysts, according to the analyst's background and purpose of use. The platform(s) could also link to an analytical toolbox to use the data and visualise the results, as demonstrated in the examples in Section 6, thus saving the local authorities significant time and effort in making good use of the car club data.

Such a platform could communicate with other ongoing and inspiring plans for data sharing, such as the micromobility platform being developed by TfL and supported by London councils, the cloud-based data platform being developed by TfGM and the ConVEx mobility data exchange being developed by TfWM.

To summarise, the ownership of the data standard and the existence and ownership of a data repository and analysis suite are independent, although related, questions to be answered. Each of these may be independently owned and operated or combined in different ways for different circumstances. Whether a data repository will act as a platform for data sharing, and whether it will incorporate a dashboard with a set of analytical tools that can be used by all local authorities, are questions that will determine the contractual details and a pathway forward.

However, the first step towards ensuring successful data sharing is to create a data standard that is easily and quickly deployable, and assigning a custodian for the data standard, who may or may not be independent from the other considerations discussed earlier. Therefore, we recommend that even as the details of the data sharing platform(s) are being ironed out, the CLADS data standard can be deployed through simpler mechanisms such as ASCII data files or CSV files shared via email with the local authorities being the data holders. This simple data exchange mechanism will fulfil the current needs of local authorities and can be established with minimal effort.

7.4 Level of granularity

As pointed out by third-party experts, the LSOA level of spatial aggregation is coarse and can be particularly limiting in less dense, semi-urban and rural parts of the country. We made the decision to aggregate at the LSOA level to address the privacy concerns of car club operators as well as the needs of local authorities. However, local authorities may not be the only data users. For instance, data and modelling experts from TfL expressed a keen interest in car club data at a lower level of spatial granularity. Also of interest to TfL and other planning organisations is the precise location (latitude/longitude) of the stops made by the car club vehicles. Such detailed vehicle trajectory data can be combined with land use and points of interest data to create a detailed car club travel diary that is comparable to data available from sources such as the London Travel Demand Survey and the National Travel Survey.

If data at a lower level of granularity is required, it is important to devise a solution to protect users' personal information. This is an active topic of research (Andrienko et al., 2010; Clifton & Gehrke, 2015; Monreale, 2012).

Another important issue for further consideration is how the current data should be adapted to dynamic data sharing. With everything else being the same, the updates would be:

- adding the co-ordinates of the parking bays in the Parking Location file;
- adding the real-time co-ordinates of available FFCS vehicles in the Vehicle Distribution file;
- adding vehicle trajectories (co-ordinates with a timestamp) of trips in the Trip Information file;
- using data exchange formats that are more suitable for real-time data sharing (i.e. JSON and XML instead of CSV/XLSX).

7.5 Extensions to the data sharing framework

Although the objective of this study was to design a data sharing framework for car club data that is easily and immediately deployable, the data sharing framework presented in this report is sufficiently flexible to allow future extensions.

Minor extensions, such as finer-grained geographical data, are easily achieved within this framework. For instance, car club users can be identified by their full address and the origins and destinations of vehicle trips can be identified as point locations. This would substantially increase the value of the data and the potential analyses that can be undertaken; in the future, this may be possible if the data repository were to be fitted with appropriate privacy preservation technologies.

Extending the framework from static data sharing to dynamic real-time data sharing is not as trivial although not technically difficult. Car club operators install GPS tracking devices on their shared vehicles and real-time data exists. However, real-time data sharing will have greater requirements for the data management system and user privacy protection.

If we were to make real-time data consistent with CLADS, operators will need to report the real-time point location (or LSOA) of their shared vehicles. This would involve the addition of a new data file to the CLADS data sharing standard that contains the GPS trajectories corresponding to each vehicle trip. Moreover, the data repository will have to be set up to enable real-time updates to the CLADS data files.

The most obvious extension to the CLADS data sharing standard involves the incorporation of other modes of shared mobility. For instance, CLADS as it currently is can be applied to shared micromobility services The only modification necessary is that 'vehicle propulsion type' is not applicable to micromobility modes; this data column could be used instead to detail the type of micromobility mode if the operator offers a mix, such as bikes, scooters, e-bikes and e-scooters.

For ridesourcing, on the other hand, two modifications will need to be made to CLADS:

- **Driver information:** Local authorities may ask operators to share driver information due to the safety concerns of passengers. Local authorities may check the background ratings of the drivers on a regular basis. Therefore, the Driver Information file can serve as an independent file containing the necessary information for each driver operating within the ridesourcing service, namely name, age, sex, years of driving, driving licence details, rating and record of passenger complaints.
- **Shared trips:** Ridesourcing offers multiple levels of service, such as Uber Pool, UberX, etc. Local authorities may want to know how many ridesourcing trips are shared car trips. To extract this information, we would need to add an additional data item recording the number of passengers in a specific trip within the Trip Information file; trip details can be recorded as the first pick-up location to the last drop-off location including the number of stops.

8. Conclusion

Car clubs are an important part of urban mobility in the UK.

They operate on public roads and are frequently provided with dedicated access to parking on public roads; hence, it is reasonable for local authorities to seek information about their operations, specifically their contributions in helping to achieve sustainability and other targets relating to transport within their area of jurisdiction.

However, car club operators, as well as their users, also have perfectly reasonable concerns regarding user and commercial privacy.

By balancing these needs through an agreed, widely applicable data sharing standard (named CLADS) that considers the interests of both local authorities and car club operators, it is hoped that value is created to all interested parties. In Section 6, we present a hypothetical case study showing a range of use cases for CLADS data to provide policy-relevant insight.

Several questions need to be answered before the CLADS data sharing standard can be operationalised, the most pressing of which are: who will own the data and who will maintain the data standard? If these are established, a simple data sharing mechanism can be easily and quickly deployed based on the standards published in this report.

Further considerations around the development of a data sharing platform and an analysis and visualisation suite are also important. Finally, it will be necessary to work with stakeholders nationwide to reach the best solution for all involved.

References

Acorn (2013). *What is Acorn?* Accessed 5 October 2020 from https://acorn.caci.co.uk/

Andrienko, G., Andrienko, N., Giannotti, F., Monreale, A., Pedreschi, D. & Rinzivillo, S. (2010). A generalisation-based approach to anonymising. Presentation at the *13th AGILE International Conference on Geographic Information Science*, 11–14 May 2010, Guimarães, Portugal. pp. 1–10.

Balac, M., Ciari, F., Axhausen, K. W. (2017). *Modeling the Impact of Parking Price Policy on Free-floating Carsharing: Case study for Zurich, Switzerland*. Transportation Research Part C: Emerging Technologies, 77: 207–225.

Baltra, G., Imana, B., Jiang, W. & Korolova, A. (2020). *On the Data Fight Between Cities and Mobility Providers*. Preprint. Accessed 5 October 2010 from https://arxiv.org/abs/2004.09072

Becker, H., Ciari, F. & Axhausen, K. (2017). *Comparing Car-Sharing Schemes in Switzerland: User groups and usage patterns*. Transportation Research Part A: Policy and Practice, 97: 17–29.

Bok, J. & Kwon, Y. (2016). *Comparable Measures of Accessibility to Public Transport Using the General Transit Feed Specification*. Sustainability 8(3): 224.

Bundesverband CarSharing (2020). *Bundesverband CarSharing*. Accessed 5 October 2020 from www.carsharing.de

Cairns, S., (2011). *Accessing Cars: Different ownership and use choices*. London: RAC Foundation.

Clifton, K. J. & Gehrke, S. R. (2015). *Hiding Private Locations by Anonymizing Data*. Accessed 5 October 2020 from https://pdxscholar.library.pdx.edu/trec_briefs/32/

Communauto (2020a). *Histoire de l'Autopartage. Liens et Références Bibliographiques (Bibliography)*. Accessed 5 October 2020 from www.communauto.com/qui/fr/bibliographie.html

Communauto (2020b). *Données Ouvertes*. Accessed 5 October 2020 from http://monstyledeville.net

CoMoUK (2018). *London Car Club Annual Survey*. Accessed 12 October 2020 from https://como.org.uk/wp-content/uploads/2019/11/CoMoUK-InfoGraphics-2018-London-FINAL.pdf

CoMoUK and Steer (2018). *England & Wales Car Club Annual Survey 2017/18*. Accessed 5 October 2020 from https://como.org.uk/wp-content/uploads/2019/06/EW-report-v4.0.pdf

CoMoUK (2019). *Car Club Annual Survey for Scotland 2019/20. Summary*. Accessed 5 October 2020 from https://como.org.uk/wp-content/uploads/2020/03/80264-Comouk-Car-Club-Survey_final-WEB-R-Edit.pdf

CoMoUK (2020a). *Shared Cars. Car Club Map*. Accessed 5 October 2020 from https://como.org.uk/shared-mobility/shared-cars/where/

CoMoUK (2020b). *Shared Cars: Who*. Accessed 5 October 2020 from https://como.org.uk/shared-mobility/shared-cars/who/

Couch, S. & Kitada Smalley, H. (2019). *Encouraging Equitable Bikeshare: Implications of docked and dockless models for spatial equity*. Preprint. Accessed 5 October 2020 from https://arxiv.org/abs/1906.00129

DfT (2020). *Future of Transport programme*. Accessed 9 November 2020 from www.gov.uk/government/collections/future-of-transport-programme#research-and-analysis

D'Agostino, M., Pellaton, P. & Brown, A. (2019). *Mobility Data Sharing: Challenges and Policy Recommendations Contributors*. Accessed 5 October 2020 from https://escholarship.org/uc/item/4gw8g9ms

Domingo-Ferrer, J. & Blanco-Justicia, A. (2020). Privacy-preserving technologies. In M. Christen et al. (eds.), *The Ethics of Cybersecurity* (pp. 279–297). Cham, Switzerland: Springer Open.

El Fassi, A., Awasthi, A. & Viviani, M. (2012). *Evaluation of Carsharing Network's Growth Strategies Through Discrete Event Simulation*. Expert Systems with Applications, 39(8): 6692–6705.

Esztergár-Kiss, D. & Kerényi, T. (2020). *Creation of Mobility Packages Based on the MaaS Concept*. Travel Behaviour and Society, 21: 307–317.

European Commission (2020). *Intelligent Transport Systems*. *Multimodal Travel Information*. Accessed 5 October 2020 from https://ec.europa.eu/transport/themes/its/road/action_plan/multimodal-travel-information_en

Ferrero, F., Perboli, G., Rosano, M. & Vesco, A. (2018). *Car-Sharing Services: An annotated review*. Sustainable Cities and Society, 37: 501–518.

Gaudette, P., Chapleau, R. & Spurr, T. (2016). *Bus Network Microsimulation with General Transit Feed Specification and Tap-in-Only Smart Card Data*. Transportation Research Record 2544(1): 71–80.

GTFS (General Transit Feed Specification) (2020). *GTFS: Making Public Transit Data Universally Accessible*. Accessed 5 October 2020 from https://gtfs.org/

Guthrie, A., Fan, Y. & Vardhan Das, K. (2017). *Accessibility Scenario Analysis of a Hypothetical Future Transit Network: Social equity implications of a general transit feed specification-based sketch planning tool*. Transportation Research Record, 2671(1): 1–9.

Habib, K. M. N., Morency, C., Islam, M. T. & Grasset, V. (2012). *Modelling Users' Behaviour of a Carsharing Program: Application of a joint hazard and zero inflated dynamic ordered probability model*. Transportation Research Part A: Policy and Practice, 46(2): 241–254.

Hadas, Y. (2013). *Assessing Public Transport Systems Connectivity Based on Google Transit Data*. Journal of Transport Geography, 33: 105–116.

Haveman, S. P., Reyes-García, J. R., Felici, E. & Bonnema, G. M. (2019). Creating effective MaaS systems: using a systems engineering approach to design an open (e)MaaS architecture. Presentation at the *13th ITS European Congress*, 3–6 June 2019, Eindhoven, the Netherlands.

Lagadic, M., Verloes, A. & Louvet, N. (2019). *Can Carsharing Services Be Profitable? A critical review of established and developing business models*. Transport Policy, 77: 68–78.

Lam, A., Schofield, M. & Ho, S.-S. (2019). Detecting (unusual) events in urban areas using bike-sharing data. In H. Chen et al. (eds.), Proceedings of the *3rd ACM SIGSPATIAL International Conference on Advances in Geographic Information Systems*. New York, NY, USA: Association for Computing Machinery. pp. 1–7.

Le Vine, S. (2012). *Car Rental 2.0. Car club innovations and why they matter*. London: RAC Foundation.

Le Vine, S., Lee-Gosselin, M., Sivakumar, A. & Polak, J. (2014). *A New Approach to Predict the Market and Impacts of Round-trip and Point-to-point Carsharing Systems: Case study of London*. Transportation Research Part D: Transport and Environment, 32: 218–229.

Martin, E. & Shaheen, S. (2011). *The Impact of Carsharing on Public Transit and Non-Motorized Travel: An exploration of North American carsharing survey data*. Energies 4 (11): 2094–2114.

Ministry of Housing, Communities and Local Government (2019). *English Indices of Deprivation 2019*. Accessed 5 October 2020 from www.gov.uk/government/statistics/english-indices-of-deprivation-2019

Ministry of Housing, Communities and Local Government (2020). *Lower Layer Super Output Areas (LSOAs)*. Accessed 5 October 2020 from https://data.gov.uk/dataset/c481f2d3-91fc-4767-ae10-2efdf6d58996/lower-layer-super-output-areas-lsoas

Monreale, A. (2012). *Privacy by Design in Data Mining*. PhD thesis. Università degli Studi di Pisa. Accessed 12 October 2020 from https://core.ac.uk/download/pdf/14702049.pdf

Morency, C., Habib, K. M. N., Grasset, V. & Islam, M. T. (2012). *Understanding Members' Carsharing (Activity) Persistency by Using Econometric Model*. Journal of Advanced Transportation, 46(1): 26–38.

Namazu, M. & Dowlatabadi, H. (2018). *Vehicle Ownership Reduction: A comparison of one-way and two-way carsharing systems*. Transport Policy, 64: 38–50.

New York City Taxi & Limousine Commission (2020). *Data*. Accessed 5 October 2020 from www1.nyc.gov/site/tlc/about/data.page

North American Bikeshare Association (2020). *GitHub – NABSA/gbfs. General Bikeshare Feed Specification*. Accessed 5 October 2020 from https://github.com/NABSA/gbfs

Northern Ireland Statistics and Research Agency (2020). *Northern Ireland Multiple Deprivation Measure 2017 (NIMDM2017)*. Accessed 5 October 2020 from www.nisra.gov.uk/statistics/deprivation/northern-ireland-multiple-deprivation-measure-2017-nimdm2017

OPAL (2018). *OPAL: The Culmination of a Decade of Data Revolution*. Accessed 12 October 2020 from https://static1.squarespace.com/static/599ef170197aeac586fed53f/t/5c9d27804e17b646243f536f/1553803141052/OPAL+Leaflet+V8.pdf

Open Mobility Foundation (2020). *GitHub – openmobilityfoundation/mobility-data-specification. Mobility Data Specification*. Accessed 5 October 2020 from https://github.com/openmobilityfoundation/mobility-data-specification

Painter, G., Boarnet, M., Swayne, M. & Miller, M. (2018). *Innovation on Job Accessibility with General Transit Feed Specification (GTFS) Data*. Accessed 12 October 2020 from https://www.metrans.org/assets/research/Tier-1-UTC_16-08_Final-Report.pdf

Pandey, S. K., Khan, M. T. & Qiu, R. (2018). Harnessing big data and analytics solutions in support of smart city services. Presentation at the *INFORMS International Conference on Service Science*, 3 November 2018, Phoenix, AZ, USA. pp. 21–30.

Puchalsky, C. M., Joshi, D. & Scherr, W. (2011). Development of a regional forecasting model based on Google Transit Feed. Presentation at the *Transportation Research Board 91st Annual Meeting*, 22–26 January 2012, Washington DC, USA. pp. 1–17.

SAE International (2018). *Taxonomy and Definitions for Terms Related to Shared Mobility and Enabling Technologies J3163_201809*. Accessed 5 October 2020 from www.sae.org/standards/content/j3163_201809/

Schreier, H., Grimm, C., Kurz, U., Schwieger, B., Keßler, S. & Möser, G. (2018). *Analysis of the Impacts of Car-Sharing in Bremen, Germany*. Accessed 5 October 2020 from https://northsearegion.eu/media/5724/analysis-of-the-impact-of-car-sharing-in-bremen-2018_team-red_final-report_english_compressed.pdf

Sevino, V. (2020). *Personal Communication*. 10 March 2020.

Scottish Government (2020). *Scottish Index of Multiple Deprivation 2020*. Accessed 5 October 2020 from www.gov.scot/collections/scottish-index-of-multiple-deprivation-2020/

Shaheen, S. & Sperling, D. (1998). *Carsharing in Europe and North American: Past, present, and future*. Transportation Quarterly, 52(3): 35–52.

Shaheen, S., Chan, N., Bansal, A. & Cohen, A. (2015). *Shared Mobility: Definitions, industry developments, and early understanding*. Accessed 5 October 2020 from http://innovativemobility.org/wp-content/uploads/2015/11/SharedMobility_WhitePaper_FINAL.pdf

Shaheen, S., Cohen, A., Randolph, M., Farrar, E., Davis, R., & Nichols, A. (2019a). *Shared Mobility Policy Playbook*. Accessed 5 October 2020 from https://escholarship.org/uc/item/9678b4xs

Shaheen, S. & Cohen A. (2019b). *Mobility on demand (MOD) and mobility as a service (MaaS). How are they similar and different?* Move Forward, 7 March. Accessed 5 October 2020 from https://medium.com/move-forward-blog/mobility-on-demand-mod-and-mobility-as-a-service-maas-how-are-they-similar-and-different-a853c853b0b8

Shaheen, S., Nelson, C., Apaar, B. & Cohen, A. (2020). Chapter 13: Sharing strategies: carsharing, shared micromobility (bikesharing and scooter sharing), transportation network companies, microtransit, and other innovative mobility modes. In E. Deakin (ed.), *Transportation, Land Use, and Environmental Planning* (pp. 237–262). Amsterdam, the Netherlands: Elsevier.

Tchervenkov, C., Balac, M., Hörl, S., Becker, H. & Axhausen, K. W. (2018). *How Much Parking Space Can Carsharing Save?* Accessed 12 October 2020 from https://www.research-collection.ethz.ch/bitstream/handle/20.500.11850/283791/ab1374.pdf?sequence=1&isAllowed=y.

TfL (Transport for London) (2015). *Assessing Transport Connectivity in London*. Accessed 5 October 2020 from https://tfl.gov.uk/cdn/static/cms/documents/connectivity-assessment-guide.pdf

TfL (2017). *Transport Classification of Londoners (TCoL)*. Accessed 5 October 2020 from http://content.tfl.gov.uk/transport-classification-of-londoners-presenting-the-segments.pdf

TfL (2020). *Our Open Data*. Accessed 5 October 2020 from https://tfl.gov.uk/info-for/open-data-users/our-open-data

Welsh Government (2020). *Welsh Index of Multiple Deprivation (Full Index Update with Ranks): 2019*. Accessed 5 October 2020 from https://gov.wales/welsh-index-multiple-deprivation-full-index-update-ranks-2019

Wessel, N., Allen, J. & Farber, S. (2017). *Constructing a Routable Retrospective Transit Timetable from a Real-Time Vehicle Location Feed and GTFS*. Journal of Transport Geography, 62: 92–97.

Wielinski, G., Trépanier, M. & Morency, C. (2019). *Exploring Service Usage and Activity Space Evolution in a Free-Floating Carsharing Service*. Transportation Research Record, 2673(8): 36–49.

Yang, L. (2019). *Personal Communication*. 23 December 2019.

Young, M., Rodriguez, L., Keller, E., Sun, F., Sa, B., Whittington, J. & Howe, B. (2019). Beyond open vs. Closed: Balancing individual privacy and public accountability in data sharing. Presentation at the *ACM FAT* 2019 Conference on Fairness, Accountability and Transparency*, 29–31 January 2019, Atlanta, GA, USA. pp. 191–200.

Zhang, A. & Lin, X. (2018). *Towards Secure and Privacy-Preserving Data Sharing in e-Health Systems via Consortium Blockchain*. Journal of Medical Systems 42: 140.

Appendices: Details of data sharing frameworks

Appendix 1: General Transit Feed Specification

File name	Mandatory or optional	Defines	Set of contents in the data file	Possible analysis that can be made
Agency.txt	Mandatory.	Transit agencies with service represented in this dataset.	Agency ID; agency name; agency URL; agency time zone; language; phone number; purchase URL; email.	Number of operators in the city.
Routes.txt	Mandatory.	Transit routes. A route is a group of trips that are displayed to riders as a single service.	Route ID; agency ID; route short/long name; route description; route type (tram, subway, etc.); route URL; route text colour; route sort order.	Number of routes in the city; types of public transport in the city.
Trips.txt	Mandatory.	Trips for each route. A trip is a sequence of two or more stops that occur during a specific time period.	Route ID; service ID; trip ID; trip headsign; trip short name; direction ID; block ID; shape ID; wheelchair accessible; bikes allowed.	Accessibility of the public transport by wheelchairs and bikes.
Stop_times.txt	Mandatory.	Times that a vehicle arrives at and departs from stops for each trip.	Trip ID; arrival time; departure time; stop ID; stop sequence; stop headsign; pick-up type; drop-off type; distance travelled.	Schedule of public transport services.

Stops.txt	Mandatory.	Stops where vehicles pick up or drop off riders. Also defines stations and station entrances.	Stop ID; stop name; stop description; stop location; zone ID. Stop URL; location type; stop time zone; wheelchair boarding; level ID; platform code.	Accessibility of stops; distribution of stops.
Calendar.txt	Mandatory.	Service dates specified using a weekly schedule with start and end dates. This file is required unless all dates of service are defined in calendar_dates.txt.	Service ID; date (Monday to Sunday); start_date; end_date.	Business hours of public transport services.
File name	**Mandatory or optional**	**Defines**	**Set of contents in the data file**	**Possible analysis that can be made**
Calendar_ dates.txt	Optional.	Exceptions for the services defined in the calendar.txt file. If calendar.txt is omitted, then calendar_dates.txt is required and must contain all dates of service.	Service ID; date; exception type.	Business hours of public transport services.
Fare_ attributes.txt	Optional.	Fare information for a transit agency's routes.	Fare ID; price; currency type; payment method; transfers; agency ID; transfer duration.	Rate and allowed payment methods of public transport.
Fare_rules. txt	Optional.	Rules to apply fares for itineraries.	Fare ID; route ID; origin ID; destination ID; contains ID.	Fare for each route.
Shapes.txt	Optional.	Rules for mapping vehicle travel paths, sometimes referred to as route alignments.	Shape ID; Shape point location; Sequence; Distance travelled.	The coverage of all routes.
Frequencies. txt	Optional.	Headway (time between trips) for headway-based service or a compressed representation of fixed-schedule service.	Trip ID; start/end time; headway seconds.	Frequencies of public transport services.
Transfers.txt	Optional.	Rules for making connections at transfer points between routes.	From/to stop; transfer type; min transfer time.	Whether it is easy for passengers transferring between routes.
Pathway.txt	Optional.	Pathways linking together locations within stations.	Pathway ID; from/ to stop ID; pathway mode; is bidirectional; length; travel time; stair count; max slope; min width; sign-posted; reversed sign-posted.	Accessibility of stations for wheelchair users.
Level.txt	Optional.	Levels within stations.	Level ID; level index; level name.	Accessibility of stations for wheelchair users.
Feed info.txt	Optional.	Dataset metadata, including publisher, version and expiration information.	Publisher name; publisher URL; language; start/end date; version; contact email; contact URL.	NA

Appendix 2: General Bikeshare Feed Specification (GBFS)

File name	Set of contents in the data file	Potential analysis that can be made
GBFS (a general document that links to all other files)	Language; name and links of all other files.	NA
GBFS version	Version number and URLs.	NA
Station information	Station ID/name; location; region ID; rental methods; capacity; rental URL for Android, iOS and WWW.	The distribution of bike sharing stations; the accessibility of bike sharing stations.
Station status	Station ID; number of bikes available/disabled[14]; number of docks available/disabled[15]; is the station currently on-street; is the station currently renting bikes/accepting bike returns; the last time this station reported its status.	Bikes/docks supply at each station.
Free bike status	Bike ID; location; is the bike reserved/disabled? rental URL for Android, iOS and WWW.	Distribution of bikes.
System hours	Is the rental hour for members or non-members?; days of week; start/end time.	Business hours of bike sharing services.
System operational calendar	Start month/day/year; end month/day/year.	Business time of bike sharing services.
System regions	Region ID; region name.	Business area of bike sharing systems.
System pricing plans	Plan ID/name; plan URL; currency; price; is it taxable?; pricing plan description.	Pricing strategy of bike sharing operators; surge pricing analysis.
System alerts	Alert ID; alert type; alert start/end time; station ID; region ID; URL; summary and description; the last time the alert was updated.	Reliability of bike sharing systems.

14 "Disabled bike" means a bike that is neither in use nor available for booking. It could be that the bike is broken and waiting to be fixed.
15 "Disabled dock" means a dock that is neither occupied by a bike nor accepting bikes to be parked. It could be that the dock is under maintenance.

Appendix 3: Mobility Data Specification

Endpoint	Set of contents in the endpoint	Potential analysis that can be made
Trips	Provider ID; provider name; device ID; vehicle ID; vehicle type; propulsion type; trip ID; trip duration; trip distance; routes; accuracy level; start time; end time; publication time; parking verification URL; standard cost; actual cost; currency.	Average vehicle operating/idle time; composition of vehicles by propulsion type; vehicle supply and customer demand; surge pricing.
Routes	All possible GPS co-ordinates collected by providers.	Trajectories of all vehicles.
Status changes	Provider ID; provider name; device ID; vehicle ID; vehicle type; propulsion type; event type (available, reserved, unavailable, removed); event type reason (user pick-up, low battery, etc.).	Average vehicle operating/idle time; vehicle supply and customer demand.
Vehicle	Provider ID (ID of shared mobility provider); provider name; device ID (ID provided by operator to uniquely identify a vehicle); vehicle ID (vehicle identification number); vehicle type (bicycle, car, scooter); propulsion type (human, electrically assisted, electric, combustion); year manufactured; vehicle manufactured; vehicle model; last vehicle event; date of last event update.	Composition of vehicles by: propulsion type, year of manufacturing, vehicle model and number of seats.
Event	Register; service start; service end; provider drop-off; provider pick-up; city pick-up; reservation; cancel reservation; trip start; trip enter; trip leave; trip end; deregister.	Vehicle supply and customer demand; average waiting time of users; vehicle redistribution by operators; number of vehicles added to/ removed from the fleet.
Vehicle telemetry	Device ID; time stamp; GPS co-ordinates; GPS altitude; GPS heading; GPS accuracy; GPS HDOP; GPS number of satellites; percentage battery charge of vehicle.	Trajectories of all vehicles; percentage battery charge of vehicles.
Area type	Parking unrestricted; parking restricted; preferred pick-up location or not; preferred drop-off location or not.	Parking spaces allowing shared vehicles to park; areas with vehicle undersupplied/ oversupplied that encourage users to drop off/pick up vehicles.
Policies	Policy ID; provider ID; description of the policy; start date; end date; policy publish date; previous policy; list of rules.	Policies that have been applied to the operators.
Rules	Name of rule; rule type; covered geography; vehicle status that this rule applies to; rule unites; vehicle type; propulsion type; rule start time; rule end time; days when the rule is in effect; message to ride user; value URL (value, timestamp and policy ID).	Information of rules that correspond to each policy.

Appendix 4: Ridesourcing Regulatory Information Platform in China

File name	Main Contents in the data files	Possible analysis that can be made
Ridesourcing operator basic information	Company ID/name/identifier; address; business scope contact address; registration capital; juristic person representative name/ID/phone/photo; vehicle number; driver number; bank name/ID/type/scope/count date; operation area; owner name; operation permission; organisation who issued permission; permission date of certification; permission start/end time; permission state.	Number of operators in the city; size of the operators (fleet size and number of drivers); number of years they have operated in the city.
Pricing	Company ID; address; fare type; fare start/end time; basic fare/mile; unit price per minute/km; morning/evening peak time start/end; peak time unit price; night-time price; another price.	Surge pricing analysis.
Vehicle basic information	Company ID; address; vehicle number and vehicle identification number; number of seats; vehicle make/model/type/colour; owner's name; engineering ID; fuel type; engine displacement; vehicle photo; vehicle permission; permission start/end time; organisation who issued permission; vehicle maintenance state; next maintenance time; GPS brand/model/ international mobile equipment identity/install date; registration date; commercial type (ridesourcing, taxi, ride sharing); fare type; insurance company/number/type/amount/start time/end time; total mileage; vehicle registration/deregistration date.	Fleet composition by fuel type/age/model/size.
File name	Contents	Possible analysis that can be made.
Driver information	Driver's name/phone/sex/birthday/nationality/marital status/education/address/photo/driving licence/is taxi driver/is full-time driver; commercial type; contract company; contract start/end time; emergency contact; number of completed trips; number of traffic violations; number of complaints received.	Driver's basic information; driver's traffic violations record; driver's service quality.
Passenger information	Passenger phone/name/sex.	Passenger basic information.
Trip information	Company ID; address; trip ID; departure/arrival time; departure/destination location; fare type; driver name/driving licence; vehicle plate number; trip cancel time/reason; car model; drive mileage/time; wait time; price (amount by cash and point of sale); bonus; peak time price; night-time price; another price; pay state; pay time.	Vehicle supply and travel demand analysis; customer waiting time; surge pricing analysis.
GPS information	Company ID; driving licence; vehicle number; position time; longitude/latitude; direction; elevation; speed; operation status.	Vehicle route track.
Service quality feedback	Company ID; trip ID; evaluation time; scores (for service, driver and vehicle); complaint time/detail.	Customers' satisfaction level.

Appendix 5: Car Club Data Standard: Milan

Information	Item	Mandatory or optional	Update frequency
Personal user information	Anonymised user ID.	Mandatory.	Monthly.
	Date of subscribing to the service.	Mandatory.	Monthly.
	Sex.	Mandatory.	Monthly.
	Year of birth.	Mandatory.	Monthly.
	Postcode of residence.	Mandatory.	Monthly.
	City of residence.	Mandatory.	Monthly.
	Active/inactive (with date of being inactive).	Mandatory.	Monthly.
	Other information related to the user.	Optional.	Monthly.
Legal entity user	Anonymised user ID.	Mandatory.	Monthly.
	Date of subscribing to the service.	Mandatory.	Monthly.
	Postcode of office location.	Mandatory.	Monthly.
	City of office location.	Mandatory.	Monthly.
	Active/inactive (with date of being inactive).	Mandatory.	Monthly.
	Anonymised user codes authorised by business customer.	Mandatory.	Monthly.
	Other information related to the user.	Optional.	Monthly.
Vehicle information	Vehicle licence plate.	Mandatory.	Monthly.
	Active/inactive (with date of being inactive).	Mandatory.	Monthly.
	Date of registration.	Mandatory.	Monthly.
	Date of vehicle being available to users.	Mandatory.	Monthly.
	Date of vehicle being removed.	Mandatory.	Monthly.
	Vehicle make and model.	Mandatory.	Monthly.
	Vehicle type (L6, L7, M1, N1).	Mandatory.	Monthly.
	Vehicle propulsion type.	Mandatory.	Monthly.
	Vehicle emission standard (Euro X).	Mandatory (if the vehicle is endothermic).	Monthly.
	Other information related to the vehicle.	Optional.	Monthly.

Information	Item	Mandatory or optional	Update frequency
Trip information	Anonymised user ID.	Mandatory.	Monthly.
	Vehicle licence plate.	Mandatory.	Monthly.
	Trip start/end time.	Mandatory.	Monthly.
	Trip start/end location.	Mandatory.	Monthly.
	Trip start/end latitude/ longitude.	Mandatory.	Monthly.
	Travel distance.	Mandatory.	Monthly.
	Total travel duration.	Mandatory.	Monthly.
	Driving time.	Mandatory.	Monthly.
	Parking time.	Mandatory (if applicable).	Monthly.
	Advance reservation or not.	Optional.	Monthly.
	Fuel/charge level at the beginning/end of the trip.	Mandatory (if available).	Monthly.
	Customer satisfaction level for external/internal condition of the vehicle.	Mandatory (if available).	Monthly.
	Other information related to the trip.	Optional.	Monthly.
Vehicle status (available)	Vehicle licence plate.	Mandatory.	Real-time.
	Time instance.	Mandatory.	Real-time.
	Vehicle position.	Mandatory.	Real-time.
	Fuel/charge level.	Optional.	Real-time.
	Customer satisfaction level for external/internal condition of the vehicle.	Mandatory (if available).	Real-time.
	Other information related to vehicle status.	Optional.	Real-time.
Vehicle status (in use)	Time instance.	Mandatory.	Real-time.
	Vehicle position.	Mandatory.	Real-time.
	Travel time (since the start of the trip).	Mandatory.	Real-time.
	Travel distance (since the start of the trip).	Mandatory.	Real-time.
	Other information related to vehicle status.	Optional.	Real-time.

Information	Item	Mandatory or optional	Update frequency
Customer satisfaction survey	Motivation of registering the service.	Mandatory (for users).	To be discussed with Municipality of Milan.
	Frequency of using the service.	Mandatory (for users).	To be discussed with Municipality of Milan.
	Number of services the user registered.	Mandatory (for users).	To be discussed with Municipality of Milan.
	Intermobility of the service towards other mobility services in Milan.	Mandatory (for users).	To be discussed with Municipality of Milan.
	Travel behaviour affected by the service.	Mandatory (for users).	To be discussed with Municipality of Milan.
	Satisfaction with the service.	Mandatory (for users).	To be discussed with Municipality of Milan.
	Suggestions to the service.	Mandatory (for users).	To be discussed with Municipality of Milan.
	Measures to reduce travel cost by private car.	Mandatory (for non-users).	To be discussed with Municipality of Milan.
	Private car travel distance per year.	Mandatory (for non-users).	To be discussed with Municipality of Milan.
	Alternative modes for private cars.	Mandatory (for non-users).	To be discussed with Municipality of Milan.
	Having season ticket for public transport or not.	Mandatory (for non-users).	To be discussed with Municipality of Milan.
	Knowledge of car club.	Mandatory (for non-users).	To be discussed with Municipality of Milan.
	Attributes that may make car club attractive.	Mandatory (for non-users).	To be discussed with Municipality of Milan.
	Perception towards the current service.	Mandatory (for non-users).	To be discussed with Municipality of Milan.

Appendix 6: Multimodal Travel Information Service (MMTIS)

Transport modes that the MMTIS is applicable to.

Scheduled

Air, rail (including high-speed rail), conventional rail, light rail, long-distance coach, maritime (including ferry, metro, tram, bus, trolleybus).

Demand-responsive

Shuttle bus, shuttle ferry, taxi, car sharing, carpooling, car hire, bike sharing, bike hire.

Personal

Car, motorcycle, cycle.

Types of static travel data

1. Level of service 1
   a. Location search (origin/destination):
      i. address identifiers (building number, street name, postcode);
      ii. topographic places (city, town, village, suburb, administrative unit);
      iii. points of interest (related to transport information) to where people may wish to travel.
   b. Trip plans:
      i. operational calendar, mapping day types to calendar dates.
   c. Location search (access nodes):
      i. identified access nodes (all scheduled modes);
      ii. geometry/map layout structure of access nodes (all scheduled modes).
   d. Trip plan computation – scheduled modes transport:
      i. connection links where interchanges may be made, default transfer times between modes at interchanges;
      ii. network topology and routes/lines (topology);
      iii. transport operators;
      iv. timetables;
      v. planned interchanges between guaranteed scheduled services;
      vi. hours of operation;
      vii. stop facilities access nodes (including platform information, help desks/ information points, ticket booths, lifts/stairs, entrance and exit locations);
      viii. vehicles (low floor, wheelchair accessible);
      ix. accessibility of access nodes and paths within an interchange, such as existence of lifts or escalators;
      x. existence of assistance services, such as existence of on-site assistance.
   e. Trip plan computation – road transport (for personal modes):
      i. road network;
      ii. cycle network (segregated cycle lanes, on-road shared with vehicles, on-path shared with pedestrians);
      iii. pedestrian network and accessibility facilities.

2. Level of service 2
    a. Location search (demand-responsive modes):
        i. park & ride stops;
        ii. bike sharing stations;
        iii. car sharing stations;
        iv. publicly accessible refuelling stations for petrol, diesel, compressed natural gas/liquefied natural gas, hydrogen-powered vehicles, charging stations for electric vehicles (EVs);
        v. secure bike parking, such as locked bike garages.
    b. Information service:
        i. where and how to buy tickets for scheduled modes, demand-responsive modes and car parking (all scheduled and demand-responsive modes including retail channels, fulfilment methods, payment methods).
    c. Trip plans, auxiliary information, availability check:
        i. Basic common standard fares (all scheduled modes):
            a. fare network data (fare zones/stops and fare stages);
            b. standard fare structures (point to point including daily and weekly fares, zonal fares, flat fares).
        ii. Vehicle facilities, such as classes of carriage, on-board Wi-Fi.
3. Level of service 3
    a. Detailed common standard and special fare query (all scheduled modes):
        i. passenger classes (classes of user such as adult, child, student, veteran; impaired access and qualifying conditions and classes of travel, such as 1st, 2nd);
        ii. common fare products (access rights, such as zone/point to point, including daily and weekly tickets/single/return, eligibility of access, basic usage conditions, such as validity period/operator/time of travel/interchanging, standard point-to-point fares prices for different point-to-point pairs, including daily and weekly fares/zonal fare prices/flat fare prices);
        iii. special fare products: offers with additional special conditions, such as promotional fares, group fares, season passes, aggregated products combining different products and add-on products, such as parking and travel, minimum stay;
        iv. basic commercial conditions, such as refunding/replacing/exchanging/transferring and basic booking conditions, such as purchase windows, validity periods, routing restrictions, zonal sequence fares, minimum stay.
    b. Information service (all modes):
        i. how to pay tolls (including retail channels, fulfilment methods, payment methods);
        ii. how to book car sharing, taxis, cycle hire, etc. (including retail channels, fulfilment methods, payment methods);
        iii. where/how to pay for car parking, public charging stations for EVs and refuelling points for compressed natural gas/liquefied natural gas, hydrogen-, petrol- and diesel-powered vehicles (including retail channels, fulfilment methods, payment methods).

Appendix 7: Interview Questions

0. Introduce the objective and background of this project

1. General background

a. Could you introduce yourself: your position, and your responsibilities?

b. Could you provide some basic information about your city (area, population, number of boroughs)?

c. Could you tell us:

- **i.** How many car club operators currently operate in your city?
- **ii.** What types of car club schemes do they operate (business-to-business, business-to-consumer, person-to-person? If it is business-to-consumer, are they round trips, one-way station-based or free-floating)?
- **iii.** What are the sizes of the car club schemes (with regards to fleet size, business area)?
- **iv.** Approximately, how many users do these operators have?

d. Do you have other mobility services (ridesourcing, bike sharing, carpooling, e-scooter, on-demand bus) operating in your city? What are the sizes of these mobility services?

2. Specific questions on data flow between municipalities and car club operators. Is there a formal data sharing arrangement between the operators and the municipality?

If **yes** …

a. How was the data sharing plan put in place? How did you find the process of reaching an agreement?

b. How many operators are currently sharing data with the municipality? What are their names?

c. What data are the operators sharing (items, degree of spatial and temporal detail)?

d. How often do the operators update the data? Are you satisfied with the frequency? What update frequency would be ideal?

e. Is data sharing automated, that is, automatically generated on a regular basis or can it be queried? Is it accessed through a special portal? Are there formal IT systems managing the data sharing? If yes, are the IT systems contracted out or in-house? If not, could you explain the reason for not having formal IT systems?

f. What data sharing framework do the operators use (standard or bespoke data/file structures and formats, including details of the database and file formats and the sharing medium)?

g. What data sharing framework would you ideally have? What are the difficulties in having such a data sharing framework?

h. Is there a formal contract between the municipality and the operator? Are you able to provide some details of this contract?

i. How did you use the data? Do you have projects that were based on the data? What questions did these projects answer?

j. Do these operators share the data with other municipalities? If yes, is this data shared using the same framework?

If **no** …

Do you have an informal data sharing arrangement?

- a. **If you have an informal data sharing arrangement:**
  - i. How many operators are currently sharing data with the municipality? What are their names?
  - ii. What data are the operators sharing (items, degree of spatial and temporal detail)? Do you find this sufficient/satisfactory to your needs?
  - iii. How often do the operators update the data? Are you satisfied with the frequency? What update frequency would be ideal?
  - iv. What are the reasons for operators not formalising the agreement?
  - v. Do you have plans for formal data sharing?
  - vi. Are operators willing to share data with you? What are the concerns of other operators?
  - vii. What data sharing framework would be ideal? Do you believe achieving such a framework will be difficult?
  - viii. Do you have a formal IT system that manages data sharing with other modes of transport? If yes, is the system contracted or in-house? If not, why not?
- b. **If you DO NOT have an informal data sharing arrangement:**
  - i. What are the reasons for operators not sharing their data?
  - ii. Do you have plans for formal/informal data sharing?
  - iii. Are operators willing to share data with you?
  - iv. What are the concerns of other operators?
  - v. What data do you think you will need?
  - vi. What data sharing framework would be ideal?
  - vii. Do you believe achieving such a framework will be difficult?
  - viii. Do you have a formal IT system that manages data sharing with other modes of transport? If yes, is the system contracted or in-house? If not, why not?

3. What do municipalities see in the future of car clubs?
   - a. Do you expect car clubs to grow in your city in the future (say 5 years)? What size do you think car clubs can grow to (number of operators, number of stations/business areas, number of users, fleet size)?
   - b. What are the most important impacts that car clubs will have on your city (car ownership, public transport, parking space, environment, congestion, etc.)?
   - c. Is developing car clubs in your long-term plans?
4. Research needs that municipalities see:
   - a. What research questions do you have on car clubs?
   - b. Do you need more data to answer these research questions? What data will you need?
   - c. How difficult will it be to obtain this data?

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